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Volta, Genius of Electricity

Phys 313.2



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VOLTAGAL GENIUS OF ELECTRICITY



"The Boys & Girls of America,"

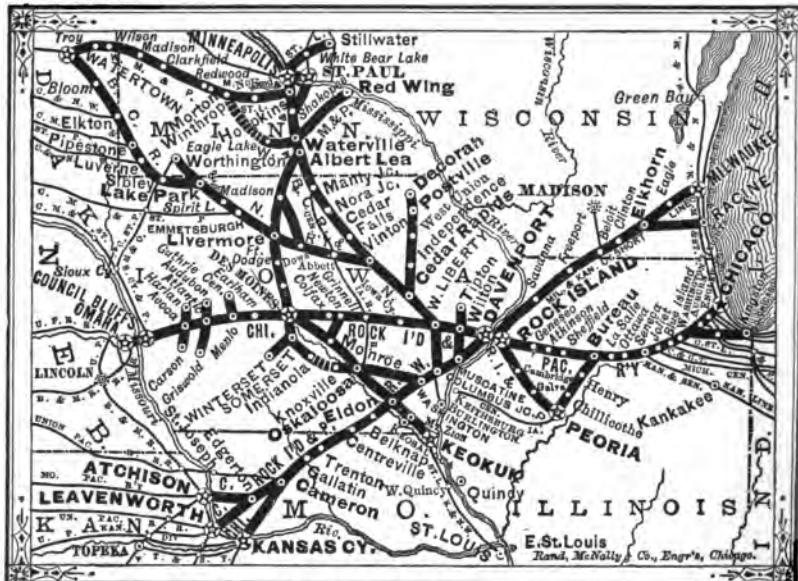
[TO WHOM THIS BOOK IS DEDICATED]

After studying Electricity with the scientific "VOLTAGAL" will be readily able to comprehend the few plain, simple facts to which we invite their attention.

The Map herewith does NOT represent a streak of lightning caught on the wing and transferred to paper. It designates what is popularly known as

THE Great Rock Island Route

And the course followed by that Railway Line between Chicago and its terminal points West, Southwest and Northwest, at Council Bluffs (Omaha), Kansas City, Leavenworth, St. Joseph, Atchison, Minneapolis, St. Paul and hundreds of rich and populous intermediate towns and cities.



[MAP OF THE GREAT ROCK ISLAND AND ALBERT LEA ROUTES.]

Not all little Boys and Girls—like "Nellie" in Dreamland, or the youthful hero of this story—are privileged to sail high up in the air on wings that are nimble and safe, or sit on a damp cloud with a wise preceptor and learn all about the wonderful forces of Nature. But if they will keep their eyes open and look sharp, they will be delighted to gaze out of the plate-glass windows of our elegant ROCK ISLAND passenger cars and catch glimpses of the beautiful landscape as it fits by, admire the horses, cattle and sheep, farms, homes, well-filled barns, villages and towns to be seen along this route. When hungry for chicken, turkey, steak, mashed potato, pie, fruits, nuts, or anything else the childish stomach craves, they will take seats with Father and Mother in the gorgeous ROCK ISLAND Dining Car and tell the waiter to bring what they want. When tired and sleepy, they will take off their clothes (just the same as at home) in one of our magnificent Pullman Palace Cars, draw the curtains, and tumble into a nice soft warm bed, to sleep the refreshing sleep of innocence. Before they reach their journey's end they will ascertain for themselves—what the general public have long since discovered—that our passenger cars of every class are unsurpassed, and that, for safety, comfort and luxury, the ROCK ISLAND ROUTE beats all creation.

Be sure you tell Pa and Ma, Aunt or Uncle, Grandpa or Grandma, when they propose to go to any point in any direction West, Northwest or Southwest of Chicago, that they must by all means buy tickets via the GREAT ROCK ISLAND ROUTE. Take them to our elegant city offices at No. 104 Clark Street, or tell them to write for information about rates or routes, or for pamphlets, maps and folders, to their and—

Your Friend,

E. ST. JOHN,

General Ticket and Passenger Agent, Chicago, Ill.

VOLTAGAL,

Genius of Electricity;

OR,

Ned Benson's Adventures and Talk with One of the Genii.

By "A MAN,"

OF THE "GREAT ROCK ISLAND ROUTE."

Respectfully Dedicated to the Boys and Girls of America, by the General Ticket and
Passenger Agent of the Chicago, Rock Island & Pacific Railway.

CHICAGO:
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1885.

Phye 313.2



— Job

"Canst thou send lightnings, that they may go,
and say unto thee, Here we are!"

—Job xxxviii : 35.

"Their line is gone out through all the earth,
and their words to the end of the world."

—Ps. xix : 4.

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INTRODUCTION.

WHEN, last year, the "A Man," of the "GREAT ROCK ISLAND ROUTE," prepared the little Christmas book entitled "WATT-STPHEN, THE GENIUS OF STEAM, or NED'S ADVENTURES WITH ONE OF THE GENII," he determined, God willing, that he would prepare a companion to it for Christmas, 1885, upon the equally instructive subjects of Electricity and Magnetism.

Nearly everything now accepted as demonstrated truth in regard to electricity, has been learned within the past one hundred years; and wonderful as have been the discoveries, and marvelous as has been the application of electricity to the uses of mankind, we are only on the threshold, so to speak, of our knowledge of this greatest of all natural forces.

When Franklin flew his kite with an iron point in its upper frame, and drew the lightning down the string to the key he had tied a little above his hand, he solved a problem that has done all the world good, for he set men to thinking in new lines, and thought induces study; study, the patient observation of phenomena; and knowledge of phenomena brings discovery of scientific principles, and the application of those principles marks the milestones along the highway of human progress and invention.

One man observes, at a given point, certain results from the operation of natural forces; another observes the same phenomena from another point, and they by and by compare the records of their watching and arrive at certain conclusions. What has been learned during the past one hundred years in relation to electricity has been learned by the study, observation and comparison of many, many men, at very many places on the globe; and while scientific men have arrayed, collated and arranged the facts, other

men not so learned in the lore of books, but more ingenious, have perfected the machinery that has made the telegraph, the telephone, the electric light and the electric motor possible.

One writer upon electricity asserts that one hundred men at least have given ten years each to the study of this great force, while hundreds of others have devoted months and years to the same subject. Probably the combined study has been equal to the study of one man for at least two thousand years, with this great advantage, that these investigations have been made all over the earth; and through the beneficent aid of the "printer's art," each investigator has had the benefit of the results obtained, and conclusions reached, by every other man's research.

In this little book the author has tried to tell the history of the efforts that have been made; the foundation truths, from knowledge of which all else has been learned, and has given certain simple experiments that are easily performed; and in all, he has tried to be accurate, and to narrate it in simple language that boys and girls can understand. He wishes it to be understood that this is not a scientific work; it is simply a narrative designed to stimulate inquiry in a field where the rewards are great.

He now launches the book, he trusts, upon the sea named public favor, hoping it will instruct and amuse those who read it, as did Watt-stephen, its predecessor. Although many thousands of Watt-stephen were printed, they were eagerly sought, and the edition early exhausted.

In conclusion, "A Man" begs to commend the great line of railway he represents to the little ones who read this volume, and to their fathers, mothers, cousins, uncles and aunts, and desires to impress upon them the fact, that when they travel, they should by all means go over our railway, if they would be carried both safely and speedily. Finally, "A Man" wishes each and every reader a most MERRY CHRISTMAS and the happiest of HAPPY NEW YEARS.

I am as always before, dear children,

Yours and the "Great Rock Island's"

Most Obedient Servant,

"A MAN."

CHAPTER I.

Ned Benson could hardly realize that Watt-stephen had really gone, and he looked around, rather expecting to again catch a glimpse of the genial Genius, whose talk and experiments had so interested him during the ride from Englewood to Davenport. Much however as Ned wanted once more to see Watt-stephen, he could not; but right by his side was the alert, active, dark-complexioned and mysterious Voltagal, whose every word came with a sudden start, like the lightning he was the Genius or impersonation of, and whose every movement made Ned involuntarily think of a Jack-in-the-box, as it seemed Voltagal was a bundle of springs endowed with life.

If Ned had been amazed at the celerity, or rapidity, of Watt-stephen's movements, he was much more surprised at the quick way Voltagal moved from place to place; and every time the Genius touched Ned, the latter heard a little snapping noise and felt that sudden tingling sensation which had so surprised him when they first shook hands on the shore of Lake Michigan.

"All aboard!" cried the conductor; the words were hardly out of his mouth before Ned found himself again in the state-room which he had before occupied with Watt-stephen.

He did not fly there; it was too rapid a movement to be called flying; the Genius simply took his hand, and quicker than a *wink* he and Ned, were in the car.

"Oh, my!" thought Ned, "this is the most astonishing thing that ever happened to a boy."

"I wonder what Mamma would say to see me going that fast?"

When the Genius said, "Be seated, Ned," the wonder of the latter grew greater yet, for right at the feet of Voltagal, was a valise, the exact counterpart of the one Watt-stephen had taken all his models from.

Now, Ned was perfectly sure that Watt-stephen took his valise with him, and that Voltagal did not have one in his hand on the platform; but there it was, and Ned was certain it contained a

lot of models that Voltagal was going to show him and make experiments with.

"The Genii are queer beings," mused Ned; "they go, and you don't see them go; they say come, and you are there."

"I really should be dreadfully frightened if Watt-stephen had not pledged me his word that I should get home all right."

"Ned," exclaimed Voltagal, "you need not be frightened; I will take just as good care of you as Watt-stephen did; and I am going to show you some more wonderful things than ne showed you. I was just talking with your mother, and she wanted me to say to you that she knows where you are, and that you may stay away as long as I want you."

"Talking with my mother!" exclaimed Ned in amazement; "I do not see how you could talk with her when she is nearly two hundred miles away; and besides, I have been here all the time, and I did not hear you,"

"Just put your mouth here," said Voltagal, "and cry hallo!" Then Ned saw hanging on the black walnut wall of the state-room an oblong box, with a little silver-plated crank on the upper half of the case, while right below it was a round orifice from which protruded a mouth-piece of ebony, while hanging to the side of the case was a long wire to which was attached a tube of black hard rubber, and from which, when Ned placed it to his ear, as the Genius directed, he distinctly heard his mother's voice inquiring, "Is that you, Ned?"*

Ned of course replied, "Yes, Mamma," and thereupon proceeded to tell her where he was, and what a good time he had had with Watt-stephen.

This talk astonished Ned more than anything that had happened before. "I see you are very surprised," said the Genius; "that is the telephone, and before we part I shall explain it to you."

"I thought it would be a pleasure to both your Mamma and yourself to talk to each other when so many miles apart."

"I thank you very much," replied Ned, "and I do want to understand how it is possible."

"You shall by and by," answered Voltagal.

"Now, Ned," said Voltagal, "we have so much to say and do, we had better commence, as Watt-stephen told you, at the beginning."

* See Chapter VI for full description of the telephone.

"First, it is best to tell you something of what man has discovered about electricity, and the manner of transmission of messages, which is called telegraphy, from two Greek words, one signifying far, far off, and the other, to write."

"The word electricity is also derived from a Greek word, *electron*, meaning amber.

"The term was invented by one Gilbert, an Englishman, who used it with reference to the well-known attractions and repulsions which amber displays when excited by friction."

"Theophrastus, 321 B. C., Thales, 600 B. C., and Pliny, 70 A. D., mention in their writings, that the amber has power, when so excited, to attract straws and dry leaves."

"Pliny wrote, 'that there was a fish called the Torpedo, which is also called the cramp fish, and is a repulsive looking creature, which is found in the Mediterranean Sea and the Atlantic Ocean, that has the power, when touched by a spear, to paralyze the muscles of the arms, and when trod upon will arrest the feet.' Aristotle added that it benumbed men and fishes which it seized for prey."

"The influence of electricity on the human body, as well as the electricity of the human body, was early known." "Anthero, a freedman of Tiberius, had the gout, and was cured by a shock from the Torpedo."

"Other ancients were cured of divers complaints, including the headache. Notwithstanding, it is only about a century ago that men began to study the science in an intelligent way, and to get from this great force results practical to humanity."

"A. the present day, when men talk of telegraphing, they are understood as meaning the sending or transmission of signals over a wire by means of electricity."

"For ages past, men have greatly desired to communicate with each other through space, the sending of letters or messages by people afoot, on horse-back, or by slow sailing vessels, being early recognized as too slow to meet certain great exigencies in human affairs."

"Among the ancient Gauls (natives of France) when there was important news to transmit, some loud-voiced young man was sent to the top of a hill or other eminence, and there he shouted the news to all points of the horizon, the words being taken up

by some other person, and thus were passed on to the utmost boundaries of the land."

"Of course, this manner of notifying the country of what was happening, was only employed in the case of great and unusual events."

"This may be styled a very picturesque way of sending forth intelligence, the sound rolling over the Nation, across forests, over mountains, valleys and plains, in the night and in the day; but it was scarcely a safe way, since if it called the tribes to war, the spies of the enemy would hear, and they would notify their generals."

"Julius Cæsar said this was a very rapid way of telegraphing, but General Sherman or General Sheridan, would say it was very slow, since they can send messages over thousands of miles of wire in a single minute of time."

"In fact, the speed of electricity is over 200,000 miles in a second of time; that is, if a wire was stretched around this earth eight times, which was absolutely, perfectly insulated, a signal could be sent around the wire in a single second of time."

"Light traverses the distance between the earth and the sun in eight minutes, which is about the same rate of speed that electricity travels."

"A locomotive engine running 60 miles an hour, and never stopping for water or fuel, would be over 17 days going around the earth, and two hundred years going to the sun."

"Other nations employed other means for communicating news rapidly; by night fires would be lighted on heights, and their arrangement would indicate the message."

"In fact, fire in one form or another has been the favorite means employed by savage tribes and nations, to warn each other of an enemy's approach."

"When you think of it, however, you will see that these means of transmission could only be employed for a small number of messages."

"It could not be employed for private purposes, to summon friends, or carry the news of the health or death of loved ones to private homes."

"Couriers were trained to ride fast and long distances, carrying letters or messages, there being every few miles fresh horses or asses, to remount and speed forward."

"For a time letters were sent from the Missouri river to California in this way. It was called the *Pony Express*."

"Other nations trained men to become runners, and in the Old Testament, you will find many instances narrated, where they were sent on ahead to announce the result of battles."

"‘Gird up thy loins,’ that is, put a girdle or strap around thy loins, and go, was a common command."

"Finally, in the course of time, pigeons, or doves as they are often called, were trained to fly long distances with messages, which they did with the almost incredible speed of from 60 to 120 miles an hour."

"France, later on, erected signal posts throughout the Kingdom, and in 1793, less than an hundred years ago, there was established a line of signals from Paris to Lille." "These signal towers were erected on high hills, or elevated points in cities, and they had movable turrets from which were suspended two long, black, movable arms, connected by an immovable bar." "The motions of these arms meant certain words or phrases, and in this way messages were quickly sent long distances; this was called the *aerial telegraph*."

"This did very well as long as it was clear weather, but in mists and fogs was quite useless."

"During the recent war in your own country, Ned, where it was inadmissible to erect a telegraph line, signals were employed to send messages between army corps and posts."

"At certain elevated points, small flags attached to long poles were waved from right to left, and back from left to right. Each of the motions from the perpendicular back right or left to the perpendicular, when there was a pause, made a letter, and the letters became, as in our language, words."

"At night torches took the place of flags." "This was called the *Signal Service*."

"When Franklin drew the electric spark down the string of his kite from the clouds, in a way which I will explain to you after awhile, it seemed plain to many that electricity might be used for the purposes of telegraphy." "But how?" "That was the question for man to solve."

"In fact, some experiments in telegraphy were made about this time, but as frictional electricity was used, the force had very little power to transmit signals long distances."

"What is frictional electricity?" interrupted Ned, who until this time had listened with almost breathless attention.

"I am going to explain that to you pretty soon," said Voltagal. "I am now only telling you the why and the how, men were impelled to study the subject; I shall very soon show you by experiments, what these scientific terms mean and what men have positively learned of this all-pervading and subtle force."

"At the beginning of the present century, galvanism was discovered; so named from Galva, a professor of anatomy in the university at Bologna, Italy."

"Previous to this discovery, numerous facts had been ascertained, but the truths had not been combined into any system. 'The electrical machines of that day, were used simply to repeat experiments which seemed extraordinary and wonderful, because not understood."

"Priests, men of fashion, as well as scientific men, would assemble around the strange apparatus, and there with the most minute precautions, and almost in awe, would discuss the subject of this unknown force, electricity."

"Here was taught, what is now known to be erroneous doctrine, that all objects including the human body, could give out sparks of fire, and to convince each other the company would join hands, while the frictional machine would be turned and a wire convey the electricity to the first person, who, being a conductor, would convey it to the second, and so on." "The shock produced was compared to the effects of lightning."

"As might have been expected, these individuals were differently impressed, according to temperament and previous habits of thought."

"Some attributed the whole matter to the devil, and flew from it as from a curse; others went about astonishing those they met, by a recital, highly imaginative, of what they had seen."

• "At one of these private scientific meetings, in the laboratory of Galvani, it so happened that that anatomist had been subjecting some frogs to a critical examination and a number of the reptiles lay skinned upon the table, where was also the electrical machine."

"As they were drawing sparks from the machine, one of the spectators touched one of the skinned frogs with the point of a scalpel which he held in his hand." "This being of steel, the

electricity flowed into the dead animal, convulsing it violently.” “In fact, its legs moved as if endowed with life.”

“Now had Franklin’s theory of lightning been understood by them, the phenomenon that astonished them would have been understood at once.”

“After repeated experiments, Galvani, asserted the astounding doctrine that the muscles and nerves of animals were reservoirs of the electric fluid.”

“Thus, to their own satisfaction for the time being, physiologists solved the mystery of life; electricity was the agent that transmitted the will power to the muscles.”

“You can easily repeat Galvani’s experiment.” “All you have to do is to remove the upper part of a frog, leaving only the hind legs and a part of the spine.”

“In removing the skin from the lower portion of the back and from the legs, the lumbar nerves, which are two whitish threads that follow the back bone, or vertebral column, as scientists say, are exposed.”

“Provide an arc, having one branch copper and one zinc, connected by being twisted together or soldered, and then with one extremity touch the lumbar nerves and with the other end the hard muscles of the thigh and you will see the muscles contract and the legs move as if about to jump.”

“Galvani, only took into account in his experiments, the nerves and muscles; the metallic circuit was a simple accessory.”

“Professor Alexander Volta found out, as Galvani had already done, that the contractions were very feeble when the circuit or arc was of only one metal.”

“He argued from this, that the development of electricity was due to the contact of the two with the nerve or muscle.” “He said where two different substances of whatever kind come into contact, there is electrical development; the dead frog only serves to manifest this.”

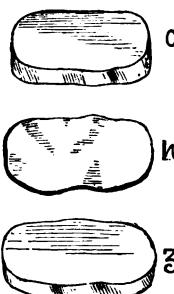
“If right, Galvani’s reservoir of electricity was wrong.” “As is often the case, each fought a wordy battle, supporting their theories with most plausible arguments, though neither was right.” “Volta, in order to sustain and bear out his theory, was led to the invention of the Voltaic pile, the instrument, of all others, which has been most prolific of results.”

"In the course of his studies and experiments, he had placed two discs in contact, both of them electrified, one being copper and the other zinc." "If this theory was correct, they should have exhibited two different kinds of electricity, positive and negative; but to his consternation they only exhibited one."

"One day, having torn up and chewed a piece of paper, it suddenly occurred to him to use the wet paper wad between the discs of metal to separate them." "He did so, and lo! each disc became electrified in a different manner."

"From this time the Voltaic pile, or battery, may be said to have been invented." "He took a series of two discs, one of copper, in the diagram I give you marked C, and one of zinc, Z,

DIAGRAM
No. 1



C, disc of copper ; h, wet cloth ; Z, disc of zinc.

soldered together." "He separated each compound plate with a circular piece of woolen cloth, moistened with a solution of common salt or diluted sulphuric acid, and placed these each above the other."

The quantity of electricity which he drew from this machine was large enough to produce shock and even sparks of fire."

"I will also give you diagrams of more modern Voltaic batteries of one and two cells.

"Figure 2 A, consists of a glass jar, a plate of zinc and one of copper with wires attached to carry off the positive electricity which comes from the copper and the negative which comes from the zinc."

"It is lettered and you can readily understand it."

"As this apparatus furnished electricity hourly under all circumstances and in a regular and continuous way, the study of electrical phenomena became both easy and simple."

"It was really the first milestone beyond the starting point." "Intelligent study would at last travel along the highway of discovery, hand in hand with facts."

FIG. 2 A.

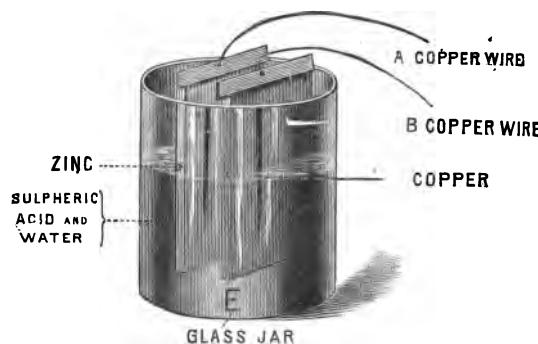


FIG. 2 B

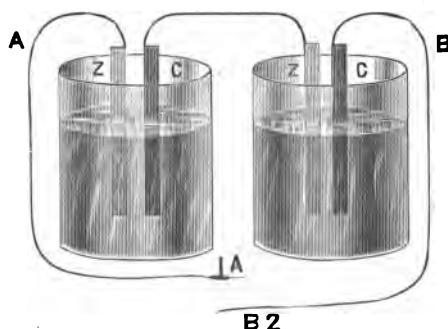


Fig. 2 B. shows a two-cell battery and the mode of coupling the metals of the same.

"When galvanism had been discovered; the Voltaic battery invented (the conductivity of metals having been previously established as well as the instantaneous action of this mysterious force); men began to say, this new form of electricity may, or ought to work the telegraph."

"Ten years later, the first chemical telegraph was invented in Philadelphia." "Two wires from a galvanic battery were made to approach each other in a cell of water." "When the galvanic circuit was closed, the water between the opposite poles, which were near each other, was decomposed and a bubble of hydrogen gas rose to the surface as gas rises in a champagne glass; thus an observer knew a current was passing, the bubble being the signal; it was of no practical value."

"In 1820, it was discovered that an electric current would deflect a magnetic needle, and Arago, and Davy, simultaneously discovered that a piece of iron, surrounded by a spiral wire through which a current of galvanism passed, would become magnetic."

"From this fact, a French scientist named Ampere, made the deduction, that magnetism was caused by the circulation of currents of electricity at right angles to the axis or line joining the two poles, or ends of the magnet."

"In 1825, Sturgeon bent a piece of wire into the shape of a horseshoe, and wound a fine wire around it in a spiral line or helix, through which the galvanic current passed; and he found that the horseshoe wire was magnetic as long as the current flowed."

"I may as well explain to you now as by and by, that galvanism is simply electricity developed by chemical action between different substances, without the aid of friction."

"It is also called galvanic-electricity, voltaic-electricity, chemico-electricity, dynamic-electricity, and by many practical electricians, current electricity: the latter because it furnishes the current or stream which electrifies telegraph wires."

"As soon as the Sturgeon magnet was discovered, an attempt was made to produce the electro-magnetic telegraph; this was not successful."

"The trouble proved to be, that the magnetic power could not be transmitted fifty feet from the battery with this magnet, and it was therefore valueless for telegraphic purposes."

"In 1829, an English professor published a scientific demonstration, which strange to say was accepted by the scientific world, that an electro-magnetic telegraph was impossible."

"In 1830, Prof. Henry of Albany, taking the hypothesis of Ampere as a fact worked out the invention now known as the

compound electro-magnet." "He then answered the English professor and proved that electro-magnetic telegraphy was possible, by sending messages over one and a half miles of wire."

"In 1831, the great Faraday of England, made known his discovery of magnetic induction." "In 1834, Gauss and Weber constructed a line of telegraph between two and three miles in length." "They generated the magneto-electric currents in a coil of wire moved up and down upon a permanent magnet around which it was placed." "The slow oscillations of a magnetic needle, which were caused by the passage of the current, and which were observed through a glass, furnished the signals for correspondence."

"Sir William Thomson, has since improved upon this and given the world a most sensitive instrument, which reflects the moving needle in a mirror and is known as the 'Thomson Galvanometer.'"

"This has been very successful in operating cables laid under the sea."

"In all experiments up to this time it was supposed there would have to be a continuous circuit of wire, from and back to the starting point; but in 1837, Steinheil discovered the important fact that the earth would serve as a conductor, thereby saving one wire."

"Then Cooke invented his electro-magnetic semaphore, by which needles were swung upon the face of a dial, as the arms of the old French semaphores were swung to convey messages, from hill top to hill top."

"Then Prof. Morse invented his electro-magnetic telegraph, and in 1844, put a line of 40 miles in operation between Washington and Baltimore." "From this time on, the electric telegraph was a fact; it was a practical invention and left to others only a field for improvement in wire, conduction and apparatus."

"In 1861, Reiss discovered that a vibrating diaphragm could be moved by the human voice so as to cause the pitch and rhythm of vocal sounds to be sent quite a distance, and be reproduced by electro-magnetism."

"From this has come the telephone, through which you talked a little while ago."

CHAPTER II.

"Now Ned," resumed the Genius, after a few minutes' pause during which he put a number of instruments together, which had been in parts in his magical valise, "I will commence our talk upon the subject of what electricity is, and what it will do, by catechising you."

"Please tell me, if you can, what electricity is?"

"Electricity," replied Ned, "is what we see flashing in the sky when there is a thunderstorm, and is what we call lightning."

"Yes, that is true," said Voltagal, "lightning is the spark or discharge of atmospheric electricity, making a vivid light." "These flashes of light are commonly from cloud to cloud; sometimes from the cloud to the earth; and passing with such inconceivable velocity through the air cause the sound we call thunder." "The distance of time between the flash and the hoarse thunder, affords the information whether the electrical disturbance is near or far away."

"One of the beneficial results of lightning, is that it burns up the germs of disease that are floating in the air." "You may have noticed, Ned, that people often exclaim after a thunder storm, how pure the air is!"

"But as for electricity itself, what it is, no man knows." I am going to tell you much about it and then leave you to study the subject in after years."

"The fact is, electricity is the most active force in nature; and it resides in the earth, the clouds, in the worlds above; in fact, is everywhere throughout the universe."

"For convenience, Ned, we will call it a fluid, though strictly speaking, it is not a fluid, for fluids are composed of substances which have particles that move easily among themselves and yield to the force of pressure, recovering their previous form when that pressure is removed." "Water and steam are fluids."

"Men say electricity is an imponderable substance, which is true to this extent, for imponderable means without weight." "Anything electrified weighs no more than when unelectrified."

"It is so quick and subtle, it will traverse thousands of miles quick as thought ; but cannot be seen and leaves no trace of its going."

"Man can produce electricity in various ways." "Take a glass tube, like this," and Voltagal produced a glass tube about a foot long, "rub it briskly with a dry flannel cloth, and the tube is electrified." "You see these bits of straw and these feathers jump toward the glass." "Now I pass this wet cloth over the glass tube and the straw and feathers are not attracted, when I place the tube near them, for the reason that the wet cloth has conducted the electricity away."

"Take a piece of sealing wax and rub that briskly, as I did the glass, and that too is electrified ; that will attract light substances also ; but remember, Ned, that if you rub two pieces of glass, each piece will repel the other, as they are both charged with the same kind of electricity ; like in electricity does not attract like."

"Now, we will take a piece of glass and put a small piece of iron on it and touch the metal to the wax ; the iron you see becomes electrified and attracts light substances just as the wax did."

"We take another piece of metal and place it on glass ; touch this metal to the electrified glass and it is electrified, for this has the same power of attraction."

"Rub two pieces of wax and each piece will repel the other and just the same will be found to be true of glass."

"Take the piece of metal which has been touched to the piece of wax and it repels the wax or any other insulated conductor which may have touched the electrified wax ; it is electrified as the wax was, and this is called resinous electricity ; it on the contrary attracts the electrified glass or any insulated conductor electrified by the glass or charged with what is called vitreous electricity."

"Those things which will not conduct away the electricity in any body are called non-conductors or insulators.'

"Glass, gutta-percha, india rubber and air are among the non-conductors ; while metals, water, the human body and damp wood are all conductors."

"You can prove that wax or resinous compounds and glass are non-conductors, for when you lay the electrified pieces on a

conductor, they do not readily lose all their electricity but remain electrified for some time in those sections which are not in the immediate neighborhood of the conductor." "Now Ned, if you have followed me closely, you have seen that part of the electricity on the wax or glass, is communicated to any body which is a conductor, which is touched by either." "More plainly, the little pieces of metal which we just electrified, have drawn off some of the electricity from the glass and wax; and the metal can give off a portion of its electricity to another conductor and so on." "There has been no gain or loss of electricity, it has simply changed habitation."

"Now what may appear strange to you, but is a fact just the same, while the insulated conductor has acquired the special properties by virtue of which the wax or glass was electrified or charged with electricity, the insulated and electrified conductor has some peculiarities which distinguish it from a similar piece of an electrified insulator."

"For instance, Ned, touch the metal which was on the wax with your finger; there, you see it will no longer attract anything, all its electricity has gone through you to the earth." "Yes," said Ned, "I thought I felt a little tingle and I suppose that was caused by the electricity going through me." "Yes," replied Voltagal, "you are right."

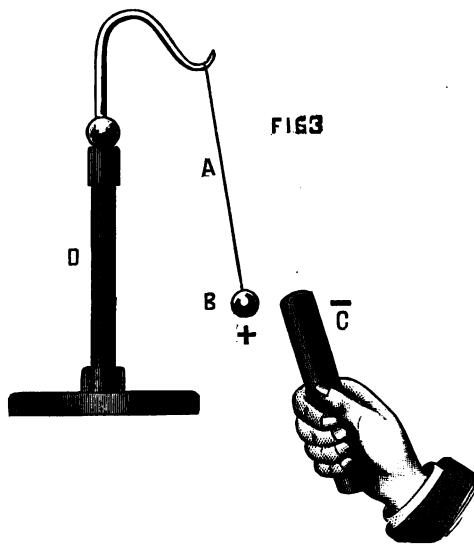
Voltagal now produced a nice, bright, clean piece of silver about the size of a half dollar and a piece of equally clean zinc of about the same size. "Take the silver and put it for a moment on your tongue and the piece of zinc under your tongue." Ned did so. "Now put both pieces together on your tongue," doing which, Ned felt a little tingle, like the pricking of a needle. "I only had you do that to amuse you," said Voltagal.

"Now, Ned, stand on this thick piece of glass and touch the other piece of electrified metal, you see it attracts these little things." "The reason is, you are insulated by standing on the glass, and the electricity could not pass through you to that greatest of all magnets, the earth."

"Now, Ned, step off the glass, and touch the electrified glass, which is an insulator, and you see it does not lose all of its electricity; now touch all parts of it, and you see its electricity is gone."

"So you find from these experiments, the insulated metal instantly lost all of its electricity by being touched by you, a conductor." "But the insulator itself, the rod of glass, only lost its electricity gradually, by your touching all parts of its surface."

"Now, Ned, I take this metal rod with a hook at one end and insert it in an insulator rising from the center of a flat, round stand. From the hook I suspend by a silk thread a gilded ball, made of elder pith." "This ball has been electrified positively or vitreously and this stick of wax has been electrified negatively or resinously." "I put the wax near the pith ball and it attracts it." "I now touch the pith ball with the wax and it is repelled."



A, silk cord insulator; B, pith ball, gilded; C, stick of wax; D, insulator. + stands for vitreous, or positive electricity. — stands for resinous, or negative electricity.

"The ball and the wax are both charged with negative or resinous electricity."

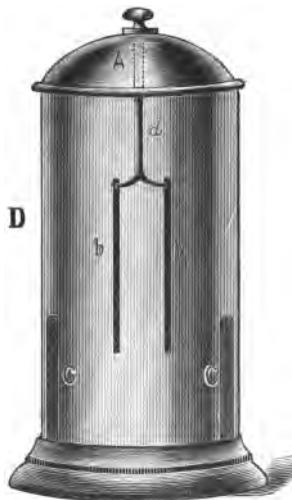
"This diagram will show you how to make this simple apparatus."

"I now take this piece of dry flannel, Ned, and shape it like a cup, attaching to it a silk thread so as to insulate it ; I now rub the wax with it and the flannel becomes charged with vitreous electricity." "Opposite effects will be produced by rubbing the pith with the flannel."

"Therefore, electrify one pith ball with negative and another with positive electricity and they will attract each other." "By having two rods with hooks you can try that experiment." "Electrify both with the same electricity and they repel each other."

"The same effect is observed by the use of two strips of gold leaf insulated and hanging side by side, a little ways apart." To illustrate to you, I take this glass case, which I place on a wooden stand." "I take this metal cap and put it on top of the case." "Through the hole in the center of this metal cap I put this metal

FIG. 4



A, metal cap; d, metal rod; b b, strips of gold leaf; c c, uninsulated strips of metal; D, glass case.

rod, with a knob on the upper end of it to hold it in place." "On the little hooks on each side of the lower end of the metal rod, I suspend these two pieces of gold leaf, and on each side of the glass case, on the inside, I stand upright two strips of metal which I do not insulate."

"I give you now, Ned, a diagram of the electroscope, each part of which is lettered and explained below the drawing."

"This little contrivance is called an electroscope, and is used to indicate the pressure of electricity by showing the existence of

a force, though it does not measure the force or the quantity of electricity." "In the electroscope the metal strips are inductively electrified by any charge of electricity applied through the metal rod suspended from which are the strips of gold leaf." "The metal strips attract the gold leaf and make them go farther apart."

"Men have found by experiments that the distribution of electricity on balls is unaffected by the mass of the ball, provided the surface is alike and remains constant." "Balls made of entirely different materials, if of the same size, and their surfaces are conductors, will act just the same so far as regards the quantity of electricity which each will abstract from any electrified body which it may touch; that is, one ball may be brass, another light wood gilded, and another a hollow iron ball, and all three, if treated alike, by contact with an electrified body, will each absorb, so to speak, the same amount of electricity."

"Therefore the weight or solidity has nothing whatever to do with its power to take electricity, while at rest, from another electrified body."

"Now, Ned, I will take from my valise a vulcanite, hard, rubber rod, which I place in a socket in this little stand."

"This is a diagram of the apparatus which you may keep."

FIG . 5.



"Now I have a ball here, which you see I take apart, it being two, hollow, half spheres (hemispheres) and I insert two vulcanite rods in sockets on each side of these half spheres." "I now take this metal ball, which is a conductor, and put it on top of the vertical (upright) vulcanite rod, and I put the two half spheres

firmlly together, enclosing the hollow iron ball." "I now electrify the system and remove the half spheres with the vulcanite handles, and find that the hollow iron ball is not electrified at all; but when I put the two half spheres together, you notice that the ball they make is in a state of electrification."

"The object I have had in this experiment was to show you that electricity, while at rest, resides only in the surface of conductors." "But while this is true, I shall show you after awhile that when electricity is in motion, it not only runs over the surface, but it passes from one conductor to another, more readily along a solid rod than along a hollow rod of same size and of the same material."

"Now we will insulate a conducting ball and electrify it by putting it in contact with a piece of electrified wax." "We take another ball, and in the same manner electrify it by putting it in contact with rubbed glass."

"Now put the two electrified balls, one of which is positive and the other negative, in contact with each other, and they are both in the same electrical condition."

"If the ball we brought in contact with the wax got a greater charge of electricity than the ball placed in contact with the rubbed glass, then both balls, after contact, are negatively charged."

"If on the other hand, the ball brought in contact with the rubbed glass got the greater charge, then both balls after contact with each other will be found charged with positive electricity."

"In all cases the quantity of electricity on the two balls after contact will be equal to the difference of the charge on the two balls at first." "If the quantity of electricity on the two balls was the same, when brought in contact, the charge would be dissipated and both balls would then be unelectrified."

"The electricity which appears on rubbed glass is positive, that on the flannel by rubbing, negative." By the terms positive or negative, we will speak of electricity hereafter." "Positive repels positive, negative repels negative; positive attracts negative and negative attracts positive."

"I had an idea," said Ned, "that there was just as much of one electricity as the other."

"There is," responded Voltagal; "when electricity is produced, there is always an equal amount of each kind produced."

"While rubbed glass has only positive, the flannel that rubbed it, has an equal amount of negative; but unless insulated, the flannel will lose its electricity by its being carried to the earth through the operator." "This will make the earth, contain a little more negative than before; but the earth and the rubbed piece of glass, contain as a whole, neither more nor less electricity than before." "Its distribution has simply been changed."

"When therefore, the entire surfaces of any two substances which have been electrified are completely connected, either through the earth or by any other conductor, the positive and negative disappear, being neutralized."

"No substance has been found to be so perfect an insulator as to keep the two electricities asunder or apart for any great length of time."

"Positive will as surely attract the negative and *vice versa*, as that the sun will rise to-morrow morning." "When one insulator is rubbed against another, one of them becomes charged with positive and the other with negative; and it is the same with any given pair of materials."

"Now Ned, I have shown you that glass rubbed with dry flannel, becomes positive; and it is the same if rubbed with silk, but I now take this cat's skin and rub glass briskly with it, and the glass is charged with negative."

"By the way, Ned, the pussy that used to wear this skin, lost her life because she did not know any better than to back up against a conductor, during a thunderstorm."

"A hot body, rubbed by a cold body identical in chemical composition becomes negatively electrified."

"When a substance charged with positive electricity, is connected with the earth, electricity is carried from the charged substance to the earth; but when a substance charged with negative electricity is connected with the earth, electricity is transferred from the earth to the body." "Remember these facts." "A body is said to be uninsulated when connected by a conductor with the earth." "The electrical condition of all uninsulated bodies, is neither negative or positive." "As you study electrical phenomena, you will hear a great deal about *induction*." "Do you know what it means?"

"I have some idea of its meaning," replied Ned, "from what you have already said; but I have not as clear an idea as I wish to have."

"Electro-magnetic induction, is the influence by which an electric or galvanic current produces magnetic polarity in certain substances near or round which it passes." "Magneto-electric induction, mark the difference, is the influence by which a magnet excites electric currents." "This fact made telegraphy possible, as I explained." "As generally understood, induction is the property which electrified or magnetic bodies possess enabling them to give off some of their own properties to other bodies with which they are not in direct contact."

"Telephone wires ought not to be strung alongside of telegraph wires, because the stronger current in the telegraph wire induces the telephone wire and people talking over the latter, will hear the click or whir of the telegraph instruments."

"Have I made this plain, Ned? If so, before we proceed with the subject of electricity proper, I will talk to you about *magnetism*."



CHAPTER III.

"Ned," resumed Voltagal, "I am going to tell you many things men have found out about magnetism; but I wish to say to you at the outset, that when electricity and magnetism are spoken of, only one agent is really alluded to." "Of the inner nature of electricity man simply knows nothing, neither does man know exactly what change a piece of iron or steel undergoes when it is magnetized by being brought under the influence of an electric current; he does know that a coil of wire with a current passing through it behaves exactly like a magnet."

"Magnetism is a name that man gave to the phenomena displayed by magnets." "Lodestone, also spelled loadstone, magnetic iron ore simply, was one of the earliest discovered magnets."

"It was named *lodestone* or *leading stone*, because it causes iron to follow it." "Your English forefathers called it *love stone*, and the French call it *l'aimant*, meaning the affectionate."

"The earth is a magnet, the greatest of all magnets." "The Greeks found the *lodestone* in Magnesia in Lydia, and they gave it the name of the Magnesian stone."

"Iron is only temporarily magnetized by contact with the lodestone, while steel is permanently magnetized by contact."

"There are very mysterious deviations in the direction and intensity of magnetic force, which seem to be explainable only by the fact that they are in subjection to emanations, or that you may better understand me, by something which comes out from the Sun, changing with the daily and yearly revolutions of that orb and throbbing in sympathy with the huge waves of fire which sweep over its surface."

"Astronomers have discovered that there are terrible storms and monster waves of fire sweeping over the Sun's surface; and when these great storms and agitation of the fiery mass take place, the magnetism of the earth receives a profound disturbance in its equilibrium, that is, in its ordinary distribution."

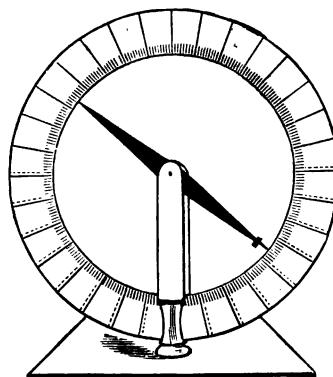
"This causes most fitful tremors in the magnets of the observatories of the earth and produces outbursts of polar light, which,

Ned, you may have noticed and heard called *Northern Lights*, *Aurora Polaris* and *Aurora Borealis*."

"In other words, solar disturbance produces magnetic disturbance on the earth and sets the northern sky ablaze with lambent flames, which dance and wave from low down on the horizon to the upper sky."

"The magnetic needle directs itself rapidly as these waves of light stream upward and the point in the sky toward which the streams of light converge, is the exact point to which the dipping needle turns." "What is a dipping needle?" queried Ned, "I never heard of one before."

FIG. 6.



DIPPING NEEDLE.

"It is a magnetic needle suspended at its exact center of gravity, and moving with perfect freedom in a vertical plane, indicating, on a graduated circle, the magnetic dip or inclination." "This diagram (Fig. 6) will convey to you an idea of its construction."

"Yes," said Ned, looking at the diagram, "I think I understand it, but I do not thoroughly understand the construction of the mariner's compass, though I have seen them often on vessels on the lake."

"The mariner's compass consists of a stiff card pivoted on a vertical axis, and directed by having on its lower surface one, two, four or more parallel magnets with similar poles pointing in

same direction." "The magnets, being free to turn in a horizontal plane, place themselves in what is called the magnetic meridian."

"The outside edge of the circle is divided into degrees and also into thirty-two parts, each containing eleven degrees (11°) and fifteen minutes ($15'$), which, you will see by multiplying, gives 360° for the whole, usually called the great circle." "The thirty-two lines or rays indicate the number of points into which the compass is divided."

"The north and south line indicates the magnetic meridian at every place where the compass may be." "I shall explain to you very soon the difference between the magnetic and the true, or geographical, north pole."

"To return to the subject, from which we digressed, I observe that, if you will notice the *northern lights* carefully, you will see that previous to the appearance of these waving streams which dance upward like never-dying flames of fire, there are concentric, circular segments, that is to say, parts of circles having a common center, almost similar in form to a rainbow, and that the two ends or extremities of these concentric segments, seem to rest on two parts of the horizon which are equally distant from the direction toward which the needle turns, and the summit or top of each arc lies exactly in that direction." "Hence the proof that there is an intimate connection between the *northern lights*, and terrestrial (which means earthly) magnetism."

"The waves of light which you will see from your point of view, move synchronously, that is at the same time, in the skies of all countries, though thousands of miles separate the regions."

"Therefore, Ned, *northern lights* are planetary phenomena; not local manifestations of the air as has generally been supposed."

"Auroral light is of an electrical character and due to bright, shining vapor, whose luminosity is due to the electric discharges sent through it."

"Now, Ned, I take this bar of slightly hardened steel (hardening is called tempering), and hold it straight up and down, striking it twenty blows near the center with this wooden mallet."

"Now I pour on this table an ounce or two of iron filings and you see the ends of the steel attract them; the steel has become magnetized. Mark the end of the steel which was toward the earth, for I want to show you a curious fact."

"Now, Ned, I produce six steel bars, and I rub one-half of the length of each of these bars lengthwise, with the end of the first bar I magnetized and which was toward the earth; now I reverse the bars and rub the remaining half with the other end of the bar I first magnetized." "I now take these iron filings, and putting any one or all of the bars near the filings you see they are attracted to the bars of steel and hang like fringe from them, heaviest near the end of the bars." "So you see every bar is now magnetized."

"In these experiments we note a remarkable fact, namely, that the first magnetized bar has lost none of its power, though it has imparted power to half a dozen bars; in fact it is stronger than it was at first." "So there could be no transfer of any substance from its body to the others; but there is the development of a latent principle."

"Now I suspend by this thread of untwisted silk one of the bars of steel, so that it lies perfectly flat or horizontal, and you see it turns one of its ends directly to the north." "This is the phenomenon called polarity."

"I may as well explain right here, that one of the extremities of an axis on which a sphere revolves is called the pole." "The axis of the earth is an imaginary line passing through the center of the earth from north to south, the north end is called the north pole and the south end the south pole."

"Toward the magnetic north pole, the loadstone or other magnet or magnetized thing, if suspended so as to be free to move on a pivot, turns one of its ends." "Therefore the magnetic north pole is that spot on the earth's surface, where the magnetic needle would dip downward and stand vertically, or upright."

"If to either end of this suspended magnetized bar, which I am holding, should approach a bar of soft iron, attraction will be exhibited between them." "When I roll a similar bar in iron filings, the iron filings will adhere in thick clusters to the two ends or poles, none will adhere to the middle of the bar." "Let me break out one inch of the center of the bar and each end of the one inch will become a pole and attract the filings, or if suspended on a pivot one end will turn to the north."

"Now I bring near to the two ends of this suspended magnet in succession the two ends of another magnetized bar, and repulsion

as well as attraction is exhibited." "By these experiments, which you can easily make, you will see that similarly magnetized ends repel each other and dissimilarly magnetized ends attract each other."

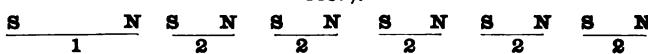
"These forces act at great distances, through all bodies between."

"I now take five pieces of soft iron and lay them on the table, end to end; then I take this first magnetized piece of steel and I lay its north pole toward the soft pieces of iron." "Now each near end of each piece of soft iron is a south pole, for all are magnetized, and each far end is a north pole." "I take away the steel bar and the polarity of the iron bars ceases."

"Now I reverse the steel bar and the near ends are north poles and the far ends south poles."

"Diagram marked number 7 will show you the arrangement."

FIG. 7.



S, south pole; N, north pole. 1, steel magnet; 2, 2, 2, 2, soft iron bars.

"The greatest manifestation of force exerted by a long, thin magnet is found to occur near its ends, and as the two ends of any one such magnet possess opposite qualities, this fact caused the name of poles to be given to the ends of long, thin magnets."

"Ordinarily these poles are looked upon as centers of force, but except in the case of long and very, very thin and uniformly magnetized rods, they cannot be considered as simply points exerting force; but as the prevailing popular conception of a magnet is a pair of poles exerting opposite forces and joined by a bar exerting no force, we will assume it to be a fact in our talk." "Now Ned, what is the magnetic axis?" "It is the line joining the two magnetic poles." "You are right, that is what it is."

"I told you that the magnetic needle turned one of its poles to the north; not, however, always, or indeed quite often to the true north." "This fact has been noted for hundreds of years; Columbus noticed it on his voyage to discover the new world; and the deviation of the needle from true north is called the variation of the needle."

"This variation is caused by the fact, that the magnetism of the earth is variable, being to a considerable degree irregular and

also subject within certain limits to almost constant changes, both in direction and intensity." "In fact, Ned, if you look at a mariner's compass you will note that it is scarcely ever stationary; it swings constantly, very slightly."

"If you have a compass with you at some point which is in the same meridian as the poles (meridian you know means an imaginary great circle passing through the poles), and say for instance your point is Greenwich, from which longitude is reckoned east or west, the needle at that point will point to the true north; but if the magnetic north lies east or west of the meridian at a given point, then the magnetic needle will deviate either east or west, and the deviation of the compass is proven." "Tens of thousands of observations of this deviation have been made at different places on the earth's surface, in order that charts might be made so that the mariner could know at all times how far from the true north the needle of his compass was pointing." "Knowing these deviations of the needle, he can by taking his longitude, tell his exact position on the great ocean."

"This magnetism is called terrestrial, because it relates to the earth." "Of the why and wherefore of these phenomena man understands but little." "It is generally accepted that terrestrial magnetism is due to currents of electricity in the earth; if so, why these currents?"

"Some say these currents are produced by thermo-electricity, which means electricity produced by heat; but how the varying heat of the sun or the high temperature of the interior of the earth can give rise to currents circulating around the earth, of such power, with such curves and bendings as would account for the observed direction and intensity of terrestrial magnetism, has not been made plain."

"Magnetic agitations, or which is the same, perturbations, were at first supposed to consist of two classes, namely, periodical and fitful." "By close observation, however, men discovered that the perturbations which they first thought were fitful, recurred at somewhat regular periods and cannot therefore be properly called fitful."

"The changes in terrestrial magnetism are of three classes."

"The first consists in a movement of the magnetic poles around the true poles of the earth from east to west, in both the northern and southern hemispheres." "This motion was discovered by

observing the changes in the position of the magnetic needle at a given place."

"The magnetic lines at any given epoch present great irregularities of shape, because very slight differences of magnetic deviation due to local peculiarities may very largely affect the position of the magnetic lines."

"But when men compared the changes of declination at any given station, they found they corresponded during the period when the observations were made, to an oscillation or vibration such as would result from the motion of the magnetic poles around the true poles of the earth, in a period of between six and seven centuries."

"In 1576, the declination needle in London pointed $11^{\circ} 15'$ east; in 1657, the needle pointed due north; in 1760, it pointed west of north by $19^{\circ} 30'$, and in 1819, it was $24^{\circ} 40'$ west." "Then the needle commenced traveling eastward, the annual rate of decrease being about ($8'$) eight minutes."

"By observing the inclination as well as the declination of the needle, men in London found that the northern magnetic pole was between London and the true north pole in the middle of the 17th century, and has since traveled westward in a direction from east to west around the true pole."

"Taking all discovered facts, man finds that the period of revolution of the magnetic pole is about 650 years."

"The second system of changes has evident relation to the annual position of the earth in its orbit around the sun and its revolution on its axis."

"At first men said this was due to the heat of the sun on different parts of the earth; but if so, why the same amount of magnetism in the southern as in the northern hemisphere; and in the temperate as in the tropical zones?"

"Magnetic force is found to be greater in the months of December, January and February, when the sun is nearest the earth, than in the months of May, June and July, when it is most distant; if the effect was due to temperature, the two hemispheres would be oppositely instead of similarly affected in each of these two periods."

"The effect must therefore be ascribed to the magnetism of the sun itself, and it must have attracting and repelling poles like the earth."

"The north pole of the needle which is attracted by the north pole of the earth, will be repelled by the north pole of the sun, and it is."

"It would take too much time, Ned, to explain all the reasons for this, so you will have to study it up and find the reasons why, when you become older."

"It is found that there is a variation of each of the magnetic elements corresponding with the daily position of the moon in regard to the earth; but this resembles the tides in exhibiting two maxima and two minima (two greatest and two least) in the course of 24 hours, regularly changing in time with the motion of the moon in her orbit around the earth."

"These phenomena indicate that the moon is not magnetic, in itself considered; but its magnetic condition resembles that of soft iron developed by the continued but varying inductive influence on account of change of distance of the earth and the sun."

"That these changes in the magnetic elements cannot be due to heat in this case must be evident, since the temperature of the moon as a mass is but little greater than that of the upper or celestial space and there it is dreadfully cold."

"The third class of magnetic variations which were formerly denominated *fitful* are now known, as I told you a while ago, to be periodical."

"Humboldt, called them magnetic storms, and Arago found they accompanied the appearance of the Aurora Borealis." "I have told you somewhat before, of the perturbations caused by what we call sun storms and the Aurora; but I did not tell you that these outbursts upon the sun's disc increase in number and magnitude of action within a period of a little more than five years, and gradually diminish through a like period, the whole cycle being completed in about eleven years."

"The periodicity of these apparently fitful variations of magnetism, coincides with the periodical recurrence of the greatest, maxima, and minima, least, area of sun spots." "These sun spots or storms often cover an area 50,000 miles in diameter."

"Men are beginning now to believe that the whole key to the series of phenomena I have just explained to you, lies in the existence of myriads of meteoric bodies traveling separately, or in systems around the sun." "They are consumed by the thousands daily in the earth's atmosphere; they pour in a countless tide,

millions upon millions upon the solar atmosphere." "To them is due the appearance of zodiacal light and the solar corona."

"Hold on," exclaimed Ned, "I do not understand what is meant by either of those terms, although I know solar relates to the sun."

"That is right, Ned, you must ask questions if you do not fully understand." "I have endeavored to use simple words, or when compelled to use hard or unusual ones, to explain their meaning."

"The zodiac, Ned, is an imaginary belt in the heavens, 16 to 18 degrees broad, in the middle of which is the ecliptic or the sun's path."

"Zodiacal light is a luminous track, of an elongated triangular figure, that is a lengthened three-sided figure, lying nearly in the ecliptic, its base being on the horizon, and its apex (which means tip, point or summit) at varying altitudes." "It is to be seen only in the evening, just after twilight and before dawn."

"The solar corona is a peculiar luminous appearance, or aureola, which surrounds the dark body of the moon during a total eclipse of the sun." "I know this planetary phenomena is hard to understand, hence I will not enlarge upon it; I only introduced it to guide your thoughts toward its study in the future, and so will drop it and return to the simpler phenomena of magnetism."

"In the popular acceptation of the word, a magnet is a piece of steel, which has acquired the peculiar properties of attracting iron to its ends." "As I said before, the particular kind of iron ore called lodestone has the same property."

"North poles of magnets are called the *negative* poles and the south poles the *positive*." "Break any magnet in two and each piece forms a complete magnet."

"The presence of a magnet in some way modifies the surrounding region, since any other magnet brought into that region experiences a peculiar force." "The neighborhood of a magnet thus affected is for convenience called a magnetic field." "Now, Ned, as an experiment, I will take these iron filings and put them on a paper over this magnetic bar and you see they arrange themselves in curves, radiating from each pole of the magnet and joining near the equator, or center of the bar." "These lines result from the fact, that each separate atom of filings, becomes by induction a separate magnet and attracts the adjacent filings, their

arrangement in this case being the same as would be the arrangement of a lot of small needles when under the influence of the two poles of a magnetic bar."

"Induction takes place readily in soft iron and disappears quite quickly when the inducing magnet is removed; while hardened steel is less quickly and powerfully induced; but retains its polarity almost permanently."

"The method by which you can make magnets of great power is as follows: Procure ten flat bars of good steel bent into the usual form of a horseshoe; have them well hardened and fitted with their flat sides together so as to form a complete magnet."

"Each of the members of this bunch can be magnetized separately to a small degree by supporting one of the legs on the lower end of a long rod of iron held nearly perpendicular and the other leg on the upper end of the same rod; or rub one leg with the north pole of a magnetized bar and the other with the south pole."

"The several horseshoes being in this way feebly magnetized, join eight of them together with their similar poles in contact, forming a compound magnet with which the remaining two bars are to be more highly magnetized."

"For this purpose lay the two shoes flat upon a table, the north pole of one in contact with the south pole of the other, so as to form a closed or continuous circuit; on any part of this circuit place the compound magnet perpendicularly, with its north pole in the direction of the south pole of the bar or shoe on which it rests, and then cause it to slide in either direction, entirely around the circuit, care being taken to have it maintain its upright position." "After having gone over the two shoes in this manner a number of times, turn the two shoes over, keeping the poles together so as not to break the circuit and repeat the process on the now upper side." "The two bars will be magnetized to an extent nearly equal to the sum of the magnetism in the bundle of the eight bars." "Now place these two bars in the bundle and take out of the eight bars, two more and lay upon the table as before and go through the same process and keep repeating until you have manipulated all the bars two or three times."

"Presently you will have a compound magnet of great power with which you can magnetize large steel or iron bars for any purpose you may desire."

"In *electro-magnetism*, the most powerful magnetic induction is produced in soft iron and this is done by taking a large piece of iron, curved in the form of a horseshoe or letter U, and winding it many times around with a light silk-wound copper wire, the extremities of which are put in connection with the two poles of a battery." "Each single turn of the wire acts separately and magnetizes the iron in some little degree, until the action, increasing with every turn of the wire, becomes very strong."

"To ascertain the strength of such a magnet a straight bar of soft iron long enough to connect the two poles or ends of the magnet, and having a ring in its center, is provided." "This bar is called an armature." "Place this upon the poles of the magnet, while the electric current is passing through the encircling wire, and it will be instantly and powerfully attracted, and held with great force."

"Weights may be suspended from the ring and thus the force of the magnet may be measured." "It will be found that the magnitude of the force will largely depend upon the size and purity of the bent bar and of the armature, the magnitude of the coil of wire and the power of the battery." "A bar two feet long and two inches in diameter can easily be made to sustain a ton."

"Professor Henry, and Dr. Ten Eyck, discovered many years ago, that 540 feet of wire used as a continuous coil, would cause a U magnet to sustain 145 pounds." "The same wire cut into nine equal pieces and each piece wound on a separate part of the magnet, the projecting ends being properly soldered to the copper and zinc cylinders of the single cell, would cause the same bar to sustain 750 pounds."

"These simple experiments pointed out how the same battery and iron bar could be made to exert a vastly greater magnetic force, with the same number of turns and feet of wire."

"This instantaneous magnetization of iron at a distance is applied to telegraphy."

"You can get your knife or other piece of steel magnetized very quickly, by laying it on the frame which supports an electric dynamo, when it is in operation, or by holding it near to a dynamo that is being used for electro-plating purposes." "I advise you, however, not to attempt it yourself but to ask the man in charge of the machines to magnetize it for you."

CHAPTER IV.

"You remember, Ned, that I have talked of the electric spark, and while I think of it, I will explain to you how it is produced."

"In all electrical machines arranged for exhibiting light, sparks are formed, between two metallic poles or pieces of wire, which are placed in contact with those parts of the machine which collect *positive* and *negative* electricity." "By the mutual attraction of the two electricities, and the struggle for union, there ensues a tension, or straining of the force of electricity at the end of the metal poles, when they are separated from each other; if this be so strong that the obstacle presented by the stratum of air between the metallic conductors is overcome by it, then the electricities are instantly united and the union takes place in that form of light and heat which is called the electric spark."

"In a little while from now, I will show you this on a grander scale than it can be demonstrated in any human laboratory, for we will go up above the earth and watch the lightning as it jumps from cloud to cloud and from cloud to earth."

"Oh ! dear me," exclaimed Ned, "I am afraid to go above the clouds; I assure you, I had much rather stay in the car and have you tell me all about it."

"My dear boy," said the Genius, "you have no cause for alarm as to your safety ; and I can assure you that you will enjoy the trip far better than any you have ever taken or will ever take again." "In after years you will look back upon it as the greatest treat of your life, and thank Voltagal for having taken you where mortals never go."

"Now are you willing ?" Some way or other, more from the manner of saying them, than from the words themselves, Ned found all his fears gone, for in fact he rather preferred to make the journey, so he quickly and heartily answered, "I know I shall enjoy it and I thank you very much for your kindness." "Spoken like a good boy," returned Voltagal.

"However, before we view a thunderstorm, I will show you some models of simple machines for producing the electric spark

and storing electricity, and I wish you to be very sure you remember all I say, as then you will better understand what you see in that phenomenon of nature, the thunderstorm."

"I shall also tell you some other facts about electricity in a rather discursive way (you know that means rambling), but which will lead you gradually along to a full comprehension of the subject of electricity, and other phenomena closely allied to it."

"A spectrum," said the Genius, "is a visible form, something seen." "When an electric spark flashes through any vapor, its light gives a spectrum, which indicates the nature, not only of the vapor, but the composition of the substances between which the spark has traveled."

"Thus if we cause an electric flash to pass between iron points through common air, we see in the spectrum upon the white screen in a darkened room, the bright lines which form the spectrum of iron, and in addition we see the bright lines belonging to the gases which form our atmosphere." "A ray of sunlight may be said to be perfectly white; but let a ray pass through a triangular piece of clear glass, called a prism, we see it reflected upon the screen as a most beautiful band of seven colors, each one being distinct as the colors of the rainbow."

"Men have converted metals into gases by the aid of electricity and thrown a ray of light as above upon a white screen, and found that each and every metal has its own peculiar line of color." "Learning what these are, they have analyzed sunlight and know the sun is consuming enormous quantities of the very metals that exist upon the earth."

"Comets' tails consist of electrical matter, the waves of light which follow these dread and erratic messengers of the sky, grow long and then shorten, being very brilliant at one time and less brilliant at another, presenting to the observer many of the features which distinguish the Aurora Borealis." "To show you what minute particles can be shown in the spectrum by electric light, I will say that you might divide a pound of salt, chemically known as *chloride of sodium*, into 500,000 parts, which would make each part a milligramme, the least particle it is possible to weigh, and then divide this minute particle into a million parts, and it will be recognized in the spectrum as salt, by the yellow of its chemical line upon the screen."

"I have told you before, Ned, that Benjamin Franklin drew from the clouds, by means of a kite (it was made of silk, with a sharp, steel point in its head), enough electricity to follow down the wet string to its end, where Franklin had fastened a key." "Below the key was a silk cord to protect his hand." "When the electricity from the cloud reached the key it discharged itself in the form of an electric spark."

"This experiment proved the identity of frictional with cloud electricity." "It is an experiment I would advise you not to repeat, for it cost a Russian scholar his life."

"You remember, that electricity developed by friction exhibits itself by attracting light bodies, as straw, feathers, etc." "Also, that electricity developed on glass is positive and that on wax or other resinous substances is negative."

"Electricity can be conveyed from one body to another by contact, and this fact furnishes the means for an experiment, by which a person can tell whether a substance is electrified positively or negatively." "That I showed you by the pith ball." "Remember, I also told you that one electricity is never developed alone." "Water holding salts in solution and in contact with the soil develops electricity, the water being usually, though not always, positive and the soil negative." "The arrangement depends upon the kind and quality of salts in solution."

"From the surface of the sea and from all water on the earth's surface, there ascends into the atmosphere, especially in hot weather, a constant stream of invisible particles of water, which condense high up in the air and form clouds."

"These particles of water, minute as they are, carry up the electricity they have acquired by contact with the earth." "Knowing this fact, we will take it as a basis to investigate the law by which it becomes so powerful as to produce the lightning which flashes across the sky."

"I now produce this little cylindrical machine, a combination, as you see, of glass and brass, with which we will experiment."

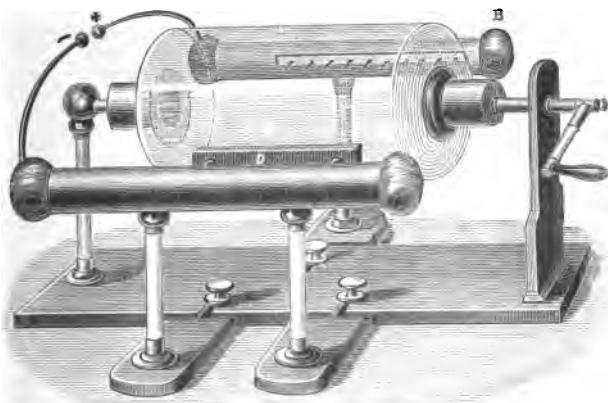
"I will now put this piece of silk on the top of the glass, so that the electricity will not go off into the air, and if you will turn the crank rapidly we will see what the result will be."

"The diagram of it, which I now give you, is lettered so that you will know from it and my description, just how it is constructed."

"Look into the space between the prime conductor and the cylinder and tell me what you see." Ned looked and replied, "I see little sparks of fire." "Now put your forefinger within half an inch of the body of the prime conductor."

Ned did so, but drew his finger quickly away, saying as he did so, "my finger feels as if it was pricked by a pin; and there was a sharp snap when it was pricked." "Now I will hang this iron chain to the prime conductor and let one end drop to the floor."

FIG. 8.



B, prime conductor; C, glass cylinder; D, rubber; —, negative electricity; +, positive electricity.

"You still see the sparks between the prime conductor and the glass cylinder, but when you put your finger near the prime conductor as before, you do not feel any shock." "Now, why is this so?"

"I think the chain is a conductor," said Ned, "and the electricity passes through it to the ground."

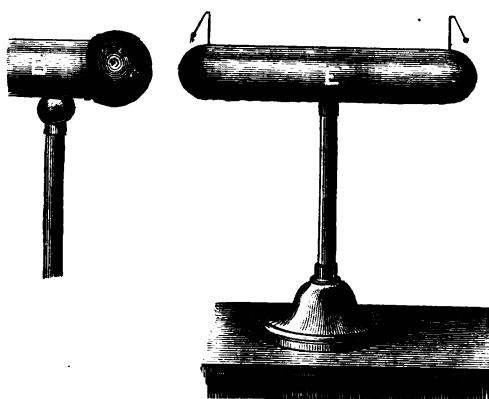
"That is correct," said Voltagal. "Until I hang the chain there, the electricity could not escape, the glass pillars and the air being non-conductors." "It accumulated in the prime conductor and you will soon see that this fact is of importance in understanding the thunderstorm." "I just said that air is a non-conductor." "It is relatively not, rather than positively not, as

electricity does pass through it in the shape of a spark of fire; but you cannot produce this spark unless there is electricity enough accumulated to burst through the resistance which the air offers."*

"We will now slightly charge the prime conductor again and put this metal cylinder, supported on a glass pillar before the end of the prime conductor, marked B, and by testing the metal cylinder E, we find one end is *positive* and the other *negative*."

"Now we will fully charge the prime conductor and cause a spark to pass and the result is, the metal cylinder is no longer

FIG. 9.



E, metal cylinder; B, end of prime conductor.

electrified, and will not be again until you put the machine in motion." "Now we will attach a metal chain to the cylinder and let it touch the ground." "We will then charge the prime conductor, and the result will be the metal cylinder has negative electricity its entire length." "We have a spark pass as before and this negative electricity disappears."

"These experiments show us that electricity can be developed in another way than by contact or friction." "As this has been brought about by the mere presence of an electrified body, the prime conductor, near an unelectrified body, this new mode of development is called *induction*."

* NOTE BY THE AUTHOR.—Is it not probable, rather, that the electricity in all cases produces a vacuum along which it travels?

"Now we will follow up this idea of induction and prove it beyond a doubt, by an experiment which is quite simple."

"I have here in my hand a glass jar about a foot high, which you see I have covered for about ten inches of its height with tin-foil." "That on the inside I have connected by a small metal wire with a metal rod surmounted by a brass ball about two inches above the cap to the jar."

"We will now connect this brass ball with the prime conductor and turn the machine." "Positive electricity now passes into the jar and accumulates on the tin-foil." "It cannot go out of the

FIG. 10.



LEYDEN JAR.

jar, as the glass, a non-conductor, prevents; but strangely it does induce negative electricity to reside on the tin foil, which is connected with the earth through the table and other materials."

"This is called a Leyden jar, and by having a number of jars, and connecting the brass balls, a battery of considerable force is made."

"With such an apparatus you can get a spark of great brilliance and strength; a flash of lightning on a small scale, accompanied by quite a loud noise."

"One jar, well charged, will give you quite a shock if you touch the metal knob with one hand and hold the jar in the other."

"The shock from a large battery of them would be dangerous to life." "With a large battery you can knock to pieces large

blocks of wood and melt thin metal wire, gold leaf and other very thin substances, and also dissipate them in vapor."

"Now you know the elementary principles of the development of electricity, by friction, by contact and by induction; and excepting the rainfall, have seen all the phenomena which nature displays in the thunderstorm, so that it ought not to be difficult for even you to trace out and explain the whole process."

"The storm is the climax of the action which, though you cannot see it, you know has been silently but surely going on." "The small particles of water evaporated have been carrying up each a little stock of electricity, and storing it away, as bees store drops of honey, until there is enough in the clouds to make the great outburst." "As the little loads of electricity increase in size by union in the form of clouds, the electricity from the same cause increases in intensity."

"The cloud becomes electrified like the inside of the Leyden jar highly charged by an electrical machine." "The air acts as the glass of the jar—and the earth is like the tin-foil on the outside, and so by induction, gets strongly charged with negative electricity, for just so far as the influence of the cloud extends."

"The electricity of the cloud being positive and the cloud movable, it is attracted toward the earth." "Now for the lightning; the cloud comes near enough for the force of electricity to overcome the resistance of the air, it leaps forth, a flash of light passes and the thunder-clap or roll follows."

"As water in contact with the earth is not always charged with *positive* electricity, it follows that there are some clouds which are charged *negatively*."

"Watch the clouds closely and you often see them rushing swiftly toward one another or receding quickly from one another."

"The *positive* cloud attracts the *negative* cloud and repels another *positive* cloud."

"Two clouds come near each other and the electricities, when near enough to overcome the resistance, unite; the flash follows, followed by the echo of the heavenly artillery."

"Sometimes you see a cloud lit up around its edges, but you see no lightning's flash." "That is because parts of the cloud separated by some little distance are differently charged and, coming toward each other, the flash of light passes."

"Now this in such cases as I just mentioned would occur on the inside of the cloud, so to speak, and therefore would not be visible to a person on the earth."

"The destruction caused by lightning is in consequence of its bursting through a bad conductor, such as stone, brick, wood or the human body." "You never see a metal rod destroyed in this way, if it is large enough to convey the charge of electricity to the ground, for if it is, it goes there every time by the conductor."

"If too small, the rod may be melted."

"Some lightning goes in a zigzag line and some forked."

"The reason of this is because the charge of electricity is exceedingly heavy and it drives the air before it, condensing it somewhat, the lightning making its aerial path where there is least resistance."

"Remove every trace of floating particles from the air, and lightning would travel a straight line."

"When you observe a flash of lightning pass from a cloud to the earth you will notice a return flash at a distance, which you can trace all through the cloud."

"I explain this by reminding you that when a flash occurs the action is not confined to the precise spot where it occurs."

"The cloud, the air between it and the earth, and the earth itself, are in a condition of strain; the positive electricity of the cloud is holding a like amount of negative on the earth, and of course every object, within a certain distance, on that surface is more or less affected."

"When the spark passes there is a rushing back of the electricities to their natural condition, and this rush produces the second flash."

"Ned, why do men put lightning rods on their houses?"

"To protect them from lightning," responded Ned. "The conductors, that is, the rods, carry off the electricity to the earth."

"Yes," answered Voltagal, "that is true, and I will explain why true." "To do this, we will once more work this glass machine."

"We saw a little while ago, that electricity passed away from a conductor when connected with the earth." "We will charge the prime conductor until we can get a spark by putting a finger near it." "There it is." "Now I will take a metal rod in my hand and let one end of it come down to the end of my forefinger."

"Now I put my finger near the prime conductor and you see no spark touches me." "It passes to the metal rod and thence through my body to the ground." "If the rod was long enough to reach the ground, not a particle of electricity would go through my body, it all would follow the rod to the earth."

"Now I take a glass rod and pursue the same course and the spark will not touch the rod, the electricity goes through my body and lets the glass alone." "If, therefore, you stood out in a thunderstorm with a long metal rod in the ground and its upper end way above your head, lightning would pass you by and strike the rod."

"If it was a glass rod, it would overlook the rod and probably kill you." "All lightning rods should be sharply pointed, a number of points are preferable, and it should tower some distance above the highest point on the house." "The other end should go into the earth to moisture." "Then it should be carefully insulated by the rod being passed through glass rings sufficiently thick to not easily break, and also to keep the rod away from the woodwork." "Experience has demonstrated that a rod fifty feet high protects one hundred feet on every side of it."

"The thunder is the snap you heard from the electric machine, only a great deal louder."

"Sound travels 1,120 feet a second, so that you can easily tell how far a storm is away from you, by noting the number of seconds between the flash and the thunder." "When Solomon built the Temple at Jerusalem, it fairly bristled with iron points, and passed unscathed through every storm."

"When the Emperor Julian undertook to rebuild it, he ignored the iron points and the 'fire came down from Heaven,' as it was expressed in the Orient, and destroyed the scaffolding on which men were laboring, killing a great many and causing the abandonment of the work."

"Herr Werner Siemens, was on top of one of the Pyramids of Girsch, when a thunderstorm came up." "He noticed that when he extended his hand toward the sky, a flow of electricity." "The Arab guides with him were very frightened, and when he capped the climax of his toying with it, by taking a gourd that had a metallic point and drew sparks from it, they rushed pell-mell down and away, not waiting even to get their pay." "They wanted nothing to do with such a man."

"Now, Ned, for an aphorism or two." "I don't know what aphorism means," said Ned.

"It means," replied the Genius, "a precept or principle that contains some important truth."

"It has been demonstrated that the quantity of electricity in a body is exactly the quantity that is necessary to decompose that body."

"For example: in a Voltaic battery of zinc and copper plates, a certain fixed quantity of electricity is eliminated." "That is, to say, given off, by the oxidation of a portion of the zinc." "If to produce this effect, the oxygen of a given measure of water, say ten drops, is necessary, the electricity developed will be exactly that which is required to separate the gaseous elements of ten drops of water from each other."

"An equivalent of electricity is developed by the oxidation of an equivalent of zinc; and that electricity is required for the decomposition of an equivalent of water, or the same quantity of electricity would be equal to the power of effecting the recombination of oxygen and hydrogen, into an equivalent of water."

"Electricity in its primitive form is deprived of all affinity in its natural state."

"Electricity is a substance somewhat transcendental, which means eminent above others, being independent of the ordinary laws of penetrability, for it appears to be capable of accumulating itself in indefinite quantity upon any body, without heeding as it were, the room which its molecules or invisible particles occupy in space."

"It does not modify in the slightest degree the aspect of bodies which absorb it, though it gives to them a new power of acting at a distance."

"This neutral electricity is especially remarkable for the surprising facility with which it is decomposed into two elements, the sole ambition of which seems to be to reunite again and which in so doing agitates the material world."

"Some eminent writers upon the subject of electricity, maintain that there are five certain sources of electricity, namely: friction, chemical action, heat, magnetism and certain peculiar organisms, as the Electric Eel and the fish called the Torpedo; and class as uncertain, contact, evaporation and solar rays."

"Read all sides of the subject carefully, conduct experiments cautiously, noting every development, comparing intelligently and you will reach proper conclusions ; but always remember, that it is easy to accept as a fact that which may be an error ; therefore, Ned, form no hasty conclusions."

"The science of *Electricity* has been divided into three branches, *electrostatics*, which deals with electricity at rest ; *electrokinetics*, which considers the passage of electricity from place to place ; and *electro-magnetism*, which treats of the relation of electricity to magnetism."

"The electricity from the clouds is called statical and that from batteries, dynamic."

"Ned, you have been a most attentive listener to what may be for some boys a rather dry subject, and so before we take our little journey, I will tell you a rather amusing thing that one Robert Symmers, of Philadelphia, discovered about electricity many years ago."

"In pulling off his stockings in the dark one night, they not only gave a crackling noise, but emitted sparks."

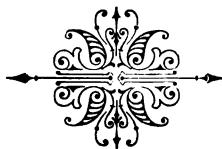
"That set him to thinking and he concluded the reason was electricity." "He then determined he would wear a worsted stocking with a silk one over it on each leg." "He did so, and when he pulled them off at night, he performed the operation by putting his hand next the leg and taking both stockings off together." "The one being then drawn out of the other, they appeared more or less inflated, and exhibited the same attractions and repulsions we have noticed in our experiments." "He soon found that two black silk stockings, or two white ones, when worn on the same leg together, exhibited none of these electrical attractions ; but when he wore a white one and a black one together, when pulled asunder, they appeared inflated and retained the shape of the leg, and though he placed them nearly eighteen inches apart, they rushed at each other as though they were mad."

"Symmers, has the merit of having first maintained the theory of two distinct fluids, not independent of each other, as Dufay supposed them to be, but co-existent and which by counteracting each other, produce all the phenomena of electricity." "He conceived that when a body is said to be *positively* electrified, it is not

simply that it is possessed of a larger share of electric matter than in a natural state; nor when it is said to be *negatively* electrified of a less, but that, in the former case it is possessed of a larger portion of one kind of electricity, and in the latter of a larger portion of the other; and that a body in its natural state remains unelectrified because there is an equal amount of the two everywhere within it."

"The story of Symmers' stockings has this moral, Ned, that men learn to master great problems by first observing closely the commonplace, or trivial, and learning then and there *why* the phenomenon presented is so."

"There has never been a great thinker, who cast aside as worthless the study of small and everyday matters, to which mankind becomes accustomed but of which the majority really know little."



CHAPTER V.

"Now, Ned, as I know you must be tired from listening so long, we will take a journey to cloumland." "Ned looked out of the window of the car, and as it was moonlight yet, he could see the fences and houses by the roadside and the growing grain and pastures where cattle lay asleep; and he could not help wondering how they would look, when he should be far above the scene, with the Genius, in the wonder-world, whither they were going." The Genius had taken all his models off of the table and put them in his valise, before he grasped Ned's hand and said, "We will go." "Ned was not conscious of moving, but it seemed to him as if the car melted away." "The green earth looked to him like a carpet and the fenced fields like rooms in some monster house." "Farther and farther the earth receded, nearer and nearer came the white, fleecy clouds, and fainter and fainter came the sounds of the crowing cocks and the lowing herds." "The Rock Island Railway, seemed like a narrow, black thread, far, far below, and he could see the moving train he had just quitted, its lights twinkling and a wreath of beautiful vapor apparently following it as it sped to the west." "Then there came to his ears the sound of a whistle, faint but musical, whereupon the Genius said, 'The train is whistling for Columbus; do you see it?'" "Ned looked right beneath him and saw what seemed to him a toy city, so tiny and small did the houses look, and by the side of the town a thread of silver, which the Genius said, was Iowa river, the stream which had given the great commonwealth its name."

"It looks like a very small city," said Ned. "That is because you are so far above it," replied the Genius. "Just then Ned was encompassed about by a sort of mist or fog, so dense that he could no longer see the earth or the sky above; and for an instant he felt very afraid."

"You are passing through a cloud now, you will soon be above it," and, sure enough, in a moment more, Ned saw the vapor he had passed through, below him, and oh! how beautiful it looked in the bright light of the morning sun, for Ned could now plainly

see that luminary, although the earth right below was still slumbering in the early twilight.

"Ned," said the Genius, as they stopped to rest on the upper edge of a portion of the cloud, which from the earth would have the appearance of the tower of a huge castle, "clouds are formed by the evaporation of water on the earth's surface, they are the collection of vapor or watery particles supported in the upper air."

"When water is evaporated into the air by the heat of the sun or by artificial heat, it is invisible to the naked eye, because of the minuteness of the water particles."

"You can readily enough understand that, after Watt-stephen's showing you the glass steam boiler, in which water was boiling furiously, but giving to your eye no evidence of steam." "It is one of the wise provisions of nature that this mixed vapor and air are transparent, allowing objects of all kinds to appear through them in their proper condition of color and form."

"You can see, Ned, that this should be so, if the surrounding objects of the material world, were to be freely visible to the eyes of animals living in the midst of surrounding air."

"When this invisible vapor reaches the upper air, there comes a change, and a very decided one; this change is a conversion of this air-like vapor into water."

"You have seen mist—it is visible because it is a clustering of molecules of water into groups of considerable size." "In the white mist the molecules of the water are not scattered, they are so grouped that there are larger spaces between the clustering particles than there were between the minute particles of the vapor; there are many of these particles united together in each clustering, or so to speak, atom of visible mist." "This is condensation."

"When water falls from great heights, the particles of water get separated through the resistance of the air, and before reaching the ground are presented as drifting mist." "So you see mist is something between water and vapor."

"This clustering of water particles, or molecules, have, when looked at through a magnifying glass, a round form." "The philosopher Halley, first announced the theory that these mist specks are hollow vesicles, the molecules of water being arranged around an interior of air; a water bladder, so to speak."

"De Saussure, strengthened Halley's observations, by ascertaining that the visible particles which rise from the surface of warm water during evaporation, have a different appearance from those which fall from above during rapid condensation of moisture." "He satisfied himself that the rising specks were hollow spheres and the falling ones liquid drops."

"Cast your eye through that rift in the cloud and you see a long trail of white appearing cloud, following the locomotive." "That is caused by the condensation of waste steam, and to all intents and purposes is the same as this cloud, upon which we are resting." "The miniature cloud trailing along behind the locomotive is visible to the naked eye because of its coarse-grained texture; in other words, the particles of moisture are not so fine as to be invisible." "Light does not freely pass through it, because the clustering vesicles, spherical in form, arrest the luminous vibrations which fall upon them and send them back to the eye; and also because these light-reflecting spherules are distributed in a deep bed, in which the remote particles present themselves through the clear spaces that lie between the nearer ones." "The cloud is white or gray, accordingly as these spheres reflect, or absorb, and hold more or less of the incident light."

"The cloud may be black if it holds back the greater part of the luminous vibrations which fall upon it; and it is white as the snow, when it freely reflects the whole of the light."

"Excuse me," said Ned, "but the subject of light has interested me very much of late, and as you have spoken two or three times of luminous vibrations, please tell me just what you mean by the expression, and also something about light."

"Light, like sound, Ned, is the product of *wave-motion*." "There has been great controversy over this subject, and most eminent thinkers and philosophers have lived and died opposing the theory." "Thomas Young and Augustus Fresnel, both gave long years to the study of the subject, and beyond a doubt, finally established the fact of *wave-motion* in light."

"In the case of sound, the velocity with which it travels depends upon the relation of elasticity to density, in the body which transmits the sound."

"The greater the elasticity, the greater is the velocity; and the less the density, the greater the velocity."

"We account for the enormous velocity of propagation of light, by the extreme elasticity and extreme tenuity, that is the extreme rarity, thinness, of the substance which transmits it, and which is named the *luminiferous ether*."

"This *ether* fills space; it surrounds the atoms of bodies; it extends without separation of continuity, through the humors of the eye." "The molecules of luminous bodies are in a state of vibration, and these vibrations are taken up by the *ether* and transmitted through it in waves." "The waves of light dashing against the retina of the eye, excite the sensation of light."

"The ancients supposed that light was produced by, and vision excited by, something emitted *from* the eye."

"Men nowadays hold vision to be excited by something that strikes the eye from without."

"Luminous bodies are only those bodies that are independent sources of light. They generate it and send it off; they do not receive their light from other bodies."

"The sun, a gas flame, a star, are examples; the moon is not a luminous body, because it borrows its light from the sun." "It is a huge reflector."

"What is an illuminated body?" asked Ned.

"Illuminated bodies are such as receive the light by which they are seen, from luminous bodies."

"You say a house is illuminated; it is receiving its light from gas, candles or electricity."

"A house, a man, a tree is illuminated and they scatter light in all directions." "You look into the dark-blue sky and you see a white cloud; you distinguish it because of its excess of light; between it and you is a large tree; you distinguish that because of its defect of light."

"If you look at any point of a visible object, the light comes from that point in perfectly straight lines to the eye." "You cannot look around a corner at an object."

"Dear me," sighed Ned, "this is a most wonderful world, there is so much for a boy to find out, I wonder if I will ever know it all." "Never," replied Voltagal, "neither is it best for you to try to comprehend everything." "Electricity and steam and their allied subjects will take up all of your time; better be really learned in a few things than half-learned in many." "Remember the old saw," "jack of all trades, master of none!"

"The form of cloud upon which we are resting, is what is called the *Heap-cloud*, *Mount-cloud* or *Cumulus*, which signifies a heap." "Looking from the earth, it assumes the look of rounded masses piled up in heaps increasing above, not downward." "This is what the vapor forms, which is puffed up from the earth into the colder atmosphere a few hundred feet above." "Here it gathers into the mist-spherules, I have told you about." "These clouds are always drifting along, they are never still." "Being constantly in motion these mist-spherules do not fall." "I have seen clouds that appeared to be perfectly still," said Ned. "Yes, they appeared so," said Voltagal, "but if you had observed closely, you would have seen that at one edge they were constantly being dissolved away and deposited at the other edge."

"Look above us way off there in the east," said Voltagal; "you see clouds that appear merely as white streaks and flowing curls, against the dark-blue of the sky." "Some of the streaks are like feathers, flowing manes and horses' tails, with some interlacing strands here and there." "Those clouds are far above us and are called *Curl-cloud* or *Cirrus*, which means a curl." "They are about six miles above the ground, and the white streaks in them are formed by particles of ice, rather than like this one, bladders of water." "The reason why this is so, is because when the moisture rose, that formed those clouds, it was very settled weather and the atmosphere was very dry, so that there was no concentration into mist, and hence there was no deposit of particles, until such an elevation was reached that ice needles of most exquisite fineness and delicacy were formed." "Those clouds are *ice-dust* instead of *water-dust*."

"Such clouds remain in that state, until there is a sudden increase of moisture from the coming in of a vapor-laden wind, which makes the streaks more abundant and of greater density, when they settle into the peculiar cloud which you see off to the left, stretched out in sheets, looking like a misty web lying in flat, long, narrow bands, rather pointed at the ends." "This is called the *Sheet-cloud* or *Stratus*, which means strewed or scattered, as it were, into a bed." "As it has come down, the ice needles have gradually been melting." "Now watch it closely; it falls still lower for the ice is quite melted into water and you notice the cloud is breaking up into little clouds, flocked and

fretted against the sky." "It is forming what is called the *Curdled-cloud*, or *Cirro-cumulus*."

"As Ned watched it, he noticed that after a little while, these flock clouds began to settle together; and soon in the part of the heavens where they were, he discovered that a dense cloud was forming, which completely shut out the light of the sun from the earth for a considerable region."

"The dark, heavy, constant cloud that you see forming now," said the Genius, "is the *Nimbus* or Rain-cloud; from such rain will descend for hours at a time or even days." "Now, Ned, we will go to a thunder cloud; there is one forming way off there, a hundred miles or so to the south."

Ned looked and saw clearly defined against the sky a long cloud or series of clouds, apparently mountain peaks, great turrets and towers, in fact many fantastic shapes, resting on a horizontal layer of cloud form, strata-like, long, irregular and narrow. "That is," said the Genius, "a *Cumulo-stratus* cloud, and it is most generally seen in very hot weather, being the sure precursor of a thunder-storm." "Now watch it closely." Ned, now perceived that the turrets, towers and peaks, were rapidly changing form and that the cloud was fast extending downward. Small clouds, flying near, were attracted toward it, and it began to show heavier and darker masses, while over its surface flitted here and there little cloudlets, as if messengers marshaling the cohorts to a great battle.

Although Ned could see light all around the now very large cloud, Voltagal told him, that those who were observing the cloud from the earth beneath could not, as it appeared to them to cover the whole sky.

Voltagal and Ned now moved nearer this cloud, so near in fact, that Ned could perceive that rain was falling from it. Suddenly, on the upper side of the cloud, two separate masses seemed to move toward each other, and he saw the lightning flash from mass to mass, and heard the deep growl of the thunder, announcing that the duel had commenced. "That was not seen down on the earth," said Voltagal; "we saw it because above it; we will now go lower."

All at once there was a flash of lightning that ran in a zigzag course from cloud to cloud, but did not reach the earth, spending

its force where there was no danger of disaster to man. A sharp peal of thunder attested the violence with which the electricity had thrust away the air to make room for its own passage.

Another minute, and a long sheet of flame, from the lower edge of the cloud, leaped to the earth, followed by a report that was fairly deafening. "That struck a large tree which you see on the bank of that stream," said Voltagal; "it was fortunate no one was under the tree."

Simultaneous, almost, with this flash was a return flash from earth to cloud, which illuminated the mass as far as Ned could see.

And thus, from parts of cloud to other parts, and from cloud to earth and back again, the marvelous force kept up its play for a full hour. It was the grandest and most impressive sight Ned had ever witnessed or was ever likely to witness. Safe from harm and at all possible altitudes and angles, the Genius allowed him to view it. At last two great cloud masses rolled rapidly toward each other, and just as Ned thought they were going to join, they suddenly started apart and receded as fast as they came; then the sunlight streamed through the rift they made and in a very short space of time the whole mass was rolling apart and away, going upward in its flight; the storm was over.

"Which whipped?" involuntarily exclaimed Ned. Voltagal smiled, as he said, "Neither whipped; General *Positive* and General *Negative* neutralized each other and are at rest." "Is there anything else you would like to see, while in Cloud-land?" queried Voltagal.

"Yes, if not too much trouble, I would like to see how snow and hail is formed in the clouds." "Take my hand then," said Voltagal, and they rose high above the light, fleecy clouds, and in a moment were hovering over a region where, as Voltagal remarked, the cotton and the palm grew; they were far in the South.

"Why have we come South where it is so much warmer?" asked Ned. "Because," answered Voltagal, "I will show you first how hail is formed, for hailstorms are much more likely to occur in warm climates than in cold." "Mexico, with her tropical climate, has most destructive hailstorms, the hailstones falling so thickly at times, they lie upon the ground knee-deep."

"Very few hailstorms occur in the temperate zone in winter ; they usually come in summer when the earth is luxuriant with vegetation, and they are preceded by thunder and lightning." "The most destructive hailstorms are accompanied by vivid electrical display and heavy thunder."

"A large majority of the hailstones which fall upon the earth are small round spherules of clear ice, of the same texture throughout, clear and with smooth surfaces." "All that is necessary for the production of hail of this character, is that there should be rain deposited in a warm, upper region of the atmosphere ; and that this should have to fall through a very cold current of air beneath." "Sleet presents itself as opaque (that is, not transparent), white grains, that look more like very small snowballs, than frozen raindrops."

"Many hailstones have been picked up in the Western and Southern States, which measured $1\frac{1}{2}$ to 2 inches across, and which were molded into the shape, as a rule, of flattened spheroids."

"Hail has fallen in Spain, that weighed $4\frac{1}{2}$ pounds ; and a German meteorologist, Kaemtz, describes a mass of hail as having fallen in Hungary, that was 39 inches in two directions and 28 inches thick."

"Such an ice block resulted from the sudden agglomeration and adhesion of separate hailstones, which being slightly melted upon the outside in descending, were driven violently together by the impact of air, due to the rush of an electric current; and then at the same instant, or as soon as the mechanical pressure was removed, encountering a stratum of intensely cold air, they were frozen solidly together in one compact mass." "Lumps of ice which are found lying upon the ground after a heavy fall of hail are usually of this character." "Some large hailstones are composed of several smaller ones, which are frozen by being driven together by the wind in their descent ; the wind usually blowing very strong during a hailstorm." "Then there are some hailstones formed in the air, which are of very good size and have not fused with any others." "They always contain a central nucleus, or kernel, of partially melted and subsequently re-frozen and closely compacted snow." "This nucleus is encased by hard transparent ice of a distinctly crystalline formation." "Now we will visit a cloud from which hail is falling."

" You see it has the appearance of a regular thunder cloud, and lightning is displayed, as we saw a few moments ago in the cloud over Iowa."

" The moisture that starts from the cloud is in the form of rain; but in descending it has to fall through air that has just been torn asunder by lightning." " You know already that the effect of a powerful electrical discharge through the atmosphere is the violent expansion of the tract of air that lies in its path."

" Air, of course, does not remain rent or torn asunder by such disruption." " The pressure coming from the elastic resistance it has met, forces the air back, and the air particles, minute and invisible as they are, clash together suddenly and impulsively."

" This makes the sonorous vibration, thunder."

" Whenever air is suddenly and violently expanded in this way, it is chilled by the expansion." " A fan will demonstrate this in a small way to you." " A large amount of sensible heat becomes latent and insensible with the production of a corresponding amount of cold."

" In the case of the discharge of lightning, the expansion is great, and the cold intense; hence the raindrop freezes and reaches the earth as hail."

" It has also been noted that large raindrops have fallen upon the earth and been instantly frozen by the mere influence of the mechanical shock."

" Hailstorms usually last but a few moments and travel in narrow belts over no great extent of territory." " All around the hail belt it may be only raining."

" I have only told you, Ned, a very small part of what can be said and learned of hailstorms. We will now turn north and see the snow fall."

As quickly as they had made the journey to Georgia, they now traveled to the very northern boundary of the United States. " Here is a snowstorm," said the Genius, " and that you may see it falling upon the earth, we will descend below the cloud." They were over a great wide plain, on which at considerable distances apart, Ned could catch sight of a human habitation.

The air was still, the weather not extremely cold, but falling lightly and gently from the cloud was the snow, covering the ground with a mantle white and pure.

"In the case of snow," said Voltagal, "the frozen particles or deposit is formed during free suspension of moisture in the air, and without any interference from contact with any solid, radiating surfaces."

"Consequently, the solid particles are grouped into regular geometrical shapes." "Snow forms in the air whenever there is two and a half grains, or more, of aqueous vapor to the cubic foot of air, provided the temperature is at least as low as 32° Fahrenheit."

"Some portion of the superfluous moisture over that which the air will sustain in an invisible state, is set free and gathers into masslets, which, with the temperature below that of freezing water, present themselves as minute needles of ice."

"When ice is formed on water, without any strain being brought to disturb its particles, on perfectly still water say, the particles are first built up by the frost into spicules or needles, and six of these bars are then grouped round a common center, like the spokes of a carriage wheel, with angular intervals of 60° between each contiguous pair of spokes." "The entire distance between the contiguous needles, represents 360°, or the same as the great circle of the earth." "That is a very curious fact," observed Ned.

"The moister the atmosphere near the surface of the earth and the nearer the temperature is to only 32° above zero, the heavier and more compact will be the snow-fall."

"The weather being very cold and the air dry, the snowflakes will be smaller and harder."

"One thing you will notice in all snow crystals, and that is, that all have the primary type of six rays and hexagonal outline."

"To verify this, gather snowflakes as they fall, on chilled yellow glass, and look at them under a magnifying glass."

"Ten inches of snow on the earth, as a rule, corresponds with one inch fall of rain."

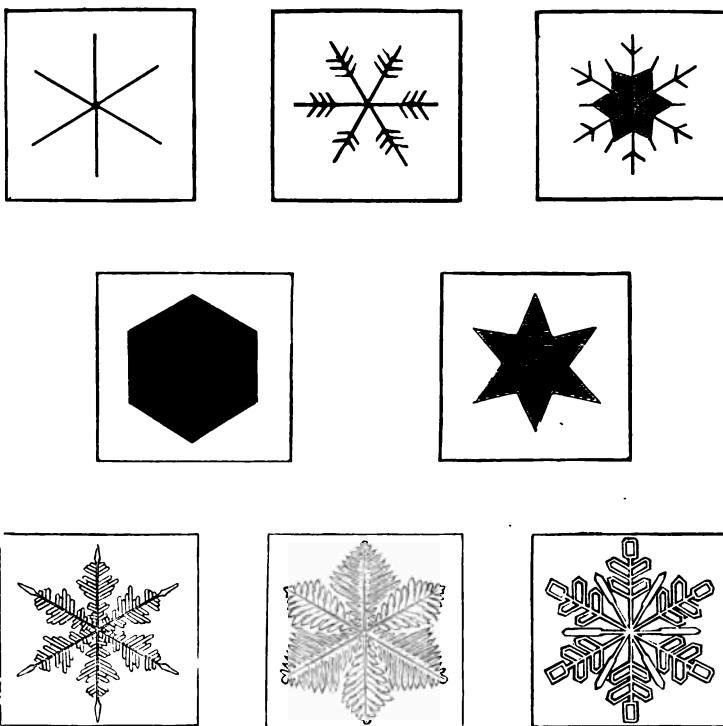
"The pure, white luster of snow, is due to the circumstance that all the elementary colors of light are blended together in the radiance that is thrown off from the surface of its crystals."

"Those colors mingled together, constitute the compound impression of whiteness upon the eye."

"It would take a great while, Ned, to give you the reasons for the formation of all the shapes snow crystals assume."

"Here is a diagram, or drawing, of snow crystals, which will show you many of the formations of the snowflake."

FIG. II.



SNOWFLAKES.

"Prof. Robert James Mann, of London, has written much and well upon this subject; and I would advise you to read what he has discovered in his researches."

Ned had never seen so much beauty in a snowflake before; and while he was admiring them, his reverie was interrupted by the Genius, who touched his hand and said "Come." Ned could scarcely believe his own eyes; there he was, back in the beautiful state-room of the car of the Great Rock Island, and the whistle sounding for Trenton.

CHAPTER VI.

Ned, looked all around the state-room and out of the door leading into the main part of the car, to determine whether he was actually once more speeding over the railway track at express speed. The car looked just as it did before he took his journey to the clouds, except that all the berths but one had been made up, and that one on the right hand side of the aisle nearest the state-room door. In that lay an old man with a countenance and nose remarkably like Punch, in the street shows of Punch and Judy, which Ned had seen. He was slumbering peacefully, although every other person in the car was up and dressed. "He is sleeping rather late," said Voltagal, "come in, let him enjoy himself."

As Ned, re-entered the state-room, he was very surprised to see the Fairy Goed-lykke, who had been with him while journeying with Watt-stephen. She smiled upon Ned just as sweetly as the night before; and if Ned knew anything about the language of the eyes, he felt very sure she was glad to see him, and in her way, was welcoming him again. Voltagal's valise was still there, and on the table were several instruments which Ned at once recognized as belonging to the outfit of a telegraph office.

"Ned," said Voltagal, "it is a most beautiful morning, and the pretty country through which we are passing looks unusually lovely." "Nature is smiling on the people, and the harvest promises to be most bountiful."

"As we must part at Kansas City," resumed Voltagal, "we will once more resume our talk about electricity." "I will endeavor to show you how the Telegraph and Telephone are operated, and explain the reasons for their successful working."

"I told you that when Volta invented his first pile, it was a great step forward in man's mastery of the science of electricity." "Although at that time it was possible to accumulate quite a stock of electricity by frictional machines, the electric fluid disappeared as soon as a way of escape was opened to it." "A force which only made itself manifest intermittently and by shocks, could, of

course, not be applied to constant work; for such purpose it was absolutely necessary that there should be a uniform and constant supply."

"You remember that I told you that Volta's pile was composed of alternate copper and zinc discs; I did not particularly explain their arrangement or size, as that really belongs to the subject with which we now have to do."

"Volta's discs were about two and one-half inches in diameter, the lower one copper, then a zinc, with a cloth wet with acid water, or salt water, between, and so on, the arrangement comprising as many pairs of discs as he desired." "These placed in a glass jar and kept in position by brass rods on each side, sent forth a constant stream of electricity."

"Connecting a wire with the copper disc at the bottom of the jar, and a wire with the zinc disc at the top, he got *positive* and *negative* electricity." "Taking these wires and putting their ends near each other, the electric spark was produced." "That proved the fact of the two kinds of electricity." "The *negative* in this arrangement flows from the wire connected with the lower, or copper disc, and the *positive* from the wire connected with the upper, or zinc disc." "This form of a column is a bad arrangement for a battery, because the moistened cloth soon becomes dry and the force of electricity diminishes."

"To remedy this, a new arrangement of the metals was adopted; cylindrical glasses were placed side by side in a row, or a porcelain trough was constructed, which was divided into, say, ten compartments."

"In each of these glasses or compartments, *cells*, as they were named, diluted sulphuric acid was poured, care being taken not to fill them entirely full, and into each *cell* was placed on end, a copper and a zinc plate, not touching each other; but the zinc plate of one cell was connected with the copper plate of the next cell by an arc of thin copper, and so on through the series." "The plates were kept in position by the copper arcs and by a rod of glass or highly varnished wood."

"This form of battery was an improvement on Volta's; but it soon lost its power, from several causes, prime among which was the decomposition of the fluid between the pairs, when the poles of the battery were connected by a conductor."

"The copper of each pair was covered by hydrogen and oxide of zinc."

"The consequence was, the plates had to be often cleaned and the force of the electricity was variable."

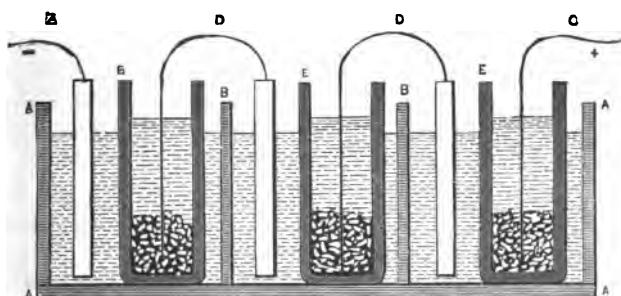
"In 1836, Daniell, in order to avoid the inconvenience I have just mentioned, conceived the idea of plunging the copper of each pair into a different liquid from that into which the zinc was plunged."

"He therefore plunged the copper into a solution of sulphate of copper and the zinc into a diluted solution of water and sulphuric acid or a solution of sea salt." "The difficulty was to separate these two liquids by some substance which, while preventing their mixture, should not alter the conductivity of the fluid (differing in kind) interposed between the plates of the pairs."

"Diaphragms of thin wood, bladder and unglazed, porous earth have all been used, the preference being given to the latter."

"The diagram I now give you, will show you how the Daniell battery looks.

FIG. 12.



SECTIONAL VIEW OF DANIELL'S BATTERY.

A A—Glass trough. B B—Glass partitions which separate it into cells. E E E—Porous earthenware pots, containing a saturated solution of sulphate of copper and surrounded by a semi-saturated solution of sulphate of zinc. A thick plate of zinc is joined by a connecting strap to a thin plate of copper at D D. The coppers stand in the porous cells, and the zincs in the sulphate of zinc. The terminal plate of copper, C, forms the positive pole of the battery, +; and the zinc, Z, has a copper wire soldered to it, which forms the negative pole, -.

"Daniell, gave the cylindrical form to the pairs of his battery, the outside jar being glass." "This he partially filled with a solution of sulphate of copper; he then introduced into that a

hollow copper cylinder, and in the interior of this cylinder he placed a hollow cylinder of porous earth, partially filled with acidulated or salt water, and into this he put a solid piece of zinc."

"Now, Ned, from all that I have told you about Volta's pile and conductors, can you tell me why a metal cylinder would not have done just as well as the one of porous earth?"

"Yes, I think I can," said Ned. "It is because there must be a conductor totally moist between all the pairs of metal; Volta's wet cloth taught me that."

"You are correct; and in all batteries, whatever their shape or form, this fundamental principle must be observed."

"There are a number of different batteries in use, for each of which some special merit is claimed; but whatever the battery, the end aimed at is a constant, steady flow of electricity."

"The Grove battery, which has been largely used, employs two liquids and two metals, zinc and platinum." "At the present time, what is known as the *gravity* battery is much used." "This employs zinc, copper and sulphate of copper; the copper at the bottom of the jar and the zinc plate suspended by a hook near the top of the jar."

"The battery is to telegraphy, exactly what the boiler is to the steam engine." "It furnishes the power."

"The electric telegraph consists of (1) the battery; (2) an insulated wire, strung upon poles or put underground in lead or other pipes, which wire in order to make a complete circuit, is grounded at both ends."

"Electricity could not be forced over an insulated wire simply suspended from one point to another and not connected with the ground at either end."

"(3) Of certain instruments called the transmitter, the relay, the sounder or the receiver."

"The telegraph is made possible by three properties or laws of electricity, as follows: "It always seeks an equilibrium in its distribution through bodies. If there is an excess in one place it always tries to transfer itself to some other place where there is a deficiency."

"In every case the production of electricity by any means is twofold, one part of the apparatus being *positive* and the other *negative*." "This fact suggests the idea of a gain on one side and a loss on the other—in fact, a *disturbance of equilibrium*."

"Some substances permit the passage of the electric fluid with perfect freedom, or, at least, with slight resistance. These bodies are conductors." "Other substances bar its progress and are called insulators." "The result of this is, that taken in connection with the two preceding laws, man is enabled to insulate electricity in an apparatus, in its two opposite conditions of *positive* and *negative*, which by its tendency to unite, causes a current to pass from the *positively* electrified body, to the *negatively* excited body, by means of a conductor, namely, the telegraph wire, which is interposed between the two."

"I think, Ned, this is plain. Do you understand it?"

"Yes, sir; I am certain I do," said Ned.

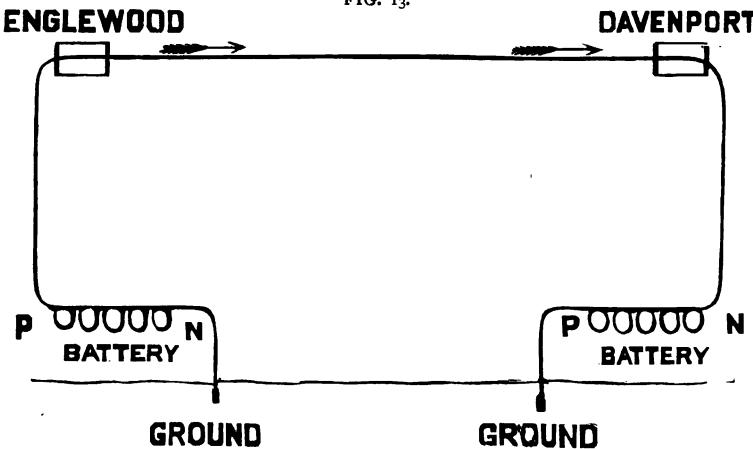
"Can you draw?" asked the Genius. "If so, I will get you to illustrate this to me."

"I have taken some drawing lessons," replied Ned, "and I will try to see what I can do."

"Suppose, then, you make me a diagram of a telegraph line, say one from your home, Englewood, to Davenport, and let me see if you have the correct idea."

This is the diagram Ned made:

FIG. 13.



P stands for positive, or +. N stands for negative, or -. The arrows show the course of the electric fluid.

"The positive pole of the battery," said Ned, "is connected with the telegraph wire at Englewood, and the negative pole with the ground." "The current flows over the wire to Davenport, to the negative pole of the battery, which is connected with the wire,

the positive pole being in the earth; as the negative pole of the Englewood battery is also grounded, the electricities unite and a complete circuit is established." "Am I right?"

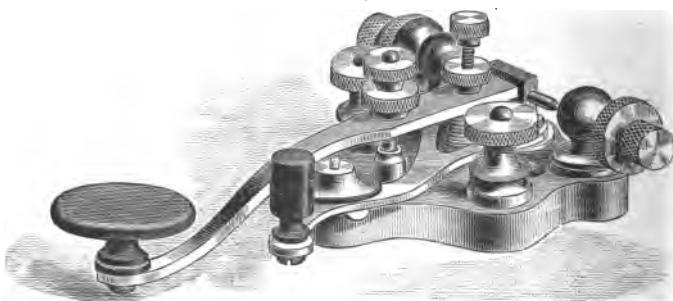
"You are perfectly correct," said Voltagal. "I could not have explained it more lucidly or in simpler language." "You not only listen, but better yet, you learn."

"Now, Ned, there are a good many telegraph offices between Englewood and Davenport, and each office is connected with, we will say, the same wire."

"This wire is carried into the station house and connected with the instruments." "At each station there is also a ground wire, which is cut off, when the circuit is complete between the terminal points."

"If the operator at Chicago or Englewood, wishes to call Ottawa, he does it by his *Signal Key* or *Transmitter*, which I now show you in this diagram :"

FIG. 14.



KEY OR TRANSMITTER.

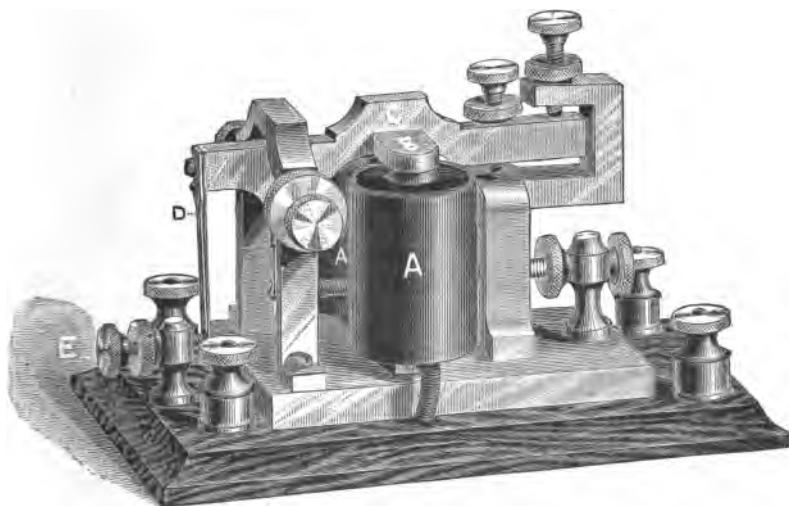
"The lever is depressed when the operator wishes to send a current, and is raised when he wishes to interrupt it." "A short depression, or mere tap, sends the short elementary signal called a dot ; a longer depression makes the dash, and both in various combinations make the alphabet, which I will give you, and which is easily learned." "The short lines are the dots and the longer lines the dashes."

"The current of electricity, which he alternately allows to flow and break, works an armature on the receiving instrument at Ottawa, the dots or the dashes, which constitute the Morse Alphabet, being represented by the longer or shorter movement

of this armature, which makes a noise by its contact with the sounding attachment."

"You notice that there are two cylinders, A, A, side by side, in this instrument, looking something like large black spools." "Within them are the arms of an electro-magnet, made of the best of Norway iron, and these cylinders, called Helices, have coiled around them, fine silk-wound copper wire, which is connected by the extremities with the line wire."

FIG. 15.



RECEIVER AT OTTAWA.

"The soft iron armature, B, you see is attached to a movable lever, C, and a spring, D, regulates the distance between the armature and the poles of the electro-magnet in the helices, the thumb screw, E, regulating the tension of the spring." "When the telegraphic circuit is opened, the electro-magnet does not act; when it is closed the electro-magnet does act and attracts the armature; when closed again the spring draws the armature back." "So you see, as the operator moves his key up and down, at Englewood, the armature at Ottawa moves synchronously and tells the listener, by the intervals of time, whether it is dots or dashes, that are being made; and the arrangement of these dots and dashes, being symbols for letters, he of course readily reads the message."

"This is, in brief, the Morse system and I now give you, Ned, the complete alphabet in use."

MORSE ALPHABET.

A - -	H -----	O - -	V - - - -
B - - -	I - -	P - - - -	W - - - -
C - - -	J - - - -	Q - - - -	X - - - -
D - - -	K - - -	R - - -	Y - - -
E -	L - - -	S - - -	Z - - -
F - - -	M - - -	T -	
G - - -	N - - -	U - - -	

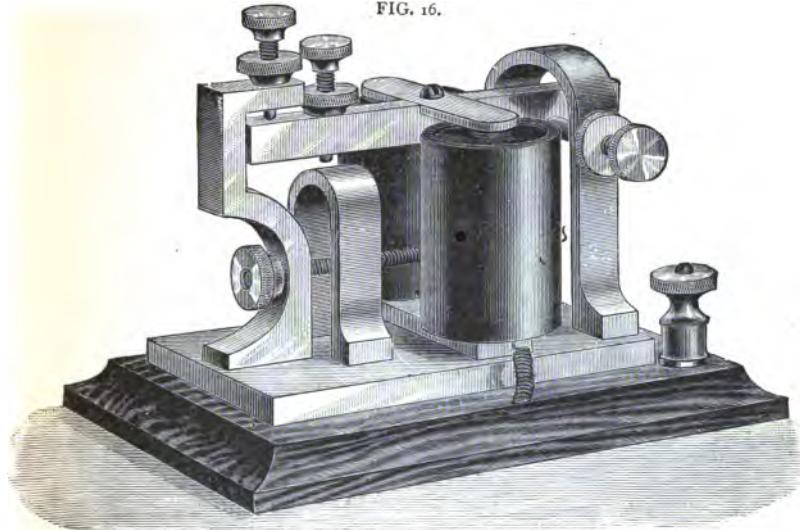
Full stop (.) - - - - -	Note of admiration (!) - - - - - - -
Colon (:) - - - - -	Hyphen (-) - - - - -
Semicolon (;) - - - - -	Apostrophe (') - - - - -
Comma (,) - - - -	Parenthesis (- - - - -)
Note of interro- } - - - - .	Inverted Commas (" ") } - - - - - - -

1 - - - - -	6 - - - - -
2 - - - - -	7 - - - - -
3 - - - - -	8 - - - - -
4 - - - - -	9 - - - - -
5 - - - - -	o - - - - -

Bar of division - - - - - - -	
Call signal - - - - - - -	
Understand message - - - - -	
Repeat message - - - - - - -	
Correction or rub out - - - - - - -	
End of message - - - - - - -	
Wait - - - - -	
Cleared out and all right - - - - - - -	
Begin another line - - - - - - -	

"In connection with this alphabet, I hand you, Ned, a figure of one of the old recording Morse instruments." "It is lettered and

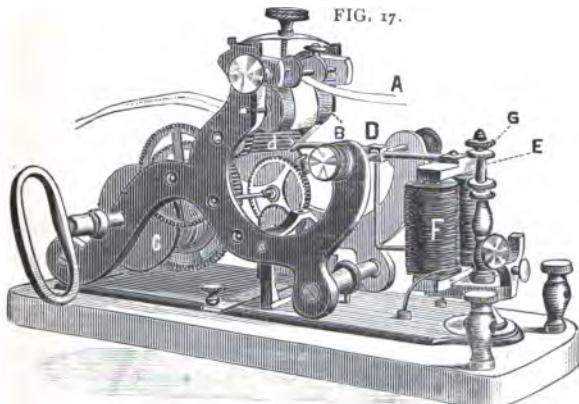
FIG. 16.



ANOTHER FORM OF SOUNDER, OR RECEIVER.

the description with it, will enable you to understand its operation."

FIG. 17.



MORSE RECORDING INSTRUMENT.

A, band of paper on which the dots and dashes are registered; B, spool upon which paper is wound; C, spring which moves machinery; D, lever pivoted in the center, on one end of which is steel point (d); and on the other end armature E, over end of electro-magnet F, and which moves up and down as the current of electricity alternately flows and ceases; G, screw which limits the play of the armature. This instrument is but little used at the present time.

"I also hand you another diagram, Figure 18, which as it is lettered and has a full description of its parts underneath, you will at once comprehend." "With a small battery and some wire you can arrange a local line in your yard or house, and it will be highly amusing to your companions."

FIG. 18.

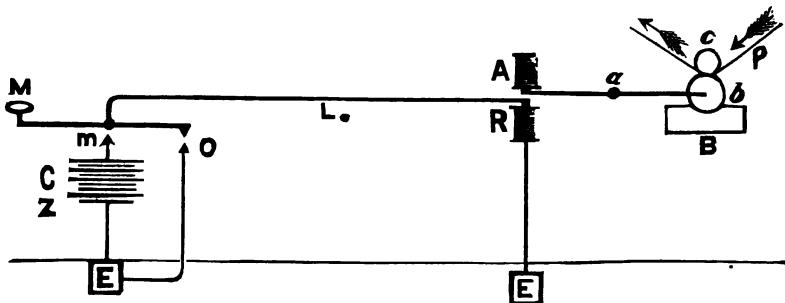


DIAGRAM
SHOWING HOW INK MARKS ARE MADE, AT THE RECEIVING END OF A LINE, INSTEAD OF DOTS AND DASHES.

M represents the Morse sounding key; L, the insulated line from sending to receiving station, where the conductor is connected to an end of the wire of an electro-magnet R, the other end of that wire being directly connected with E in the earth. Let A be a soft iron armature hinged at a, and having a narrow roller b, continually revolving in an ink trough B. The strip of paper P, is continually moving in the direction of the arrows. When M is depressed, making contact at *m*, with one pole of a battery, CZ, the other pole of which is to earth, a current will flow through the whole circuit, and make the core of R magnetic. The end A of the armature, will then be depressed and the little roller pressed against the paper, and a black mark made, the length of which will depend on the rate at which the paper is moved, and the time M remains depressed. On raising the handle, M, contact is made at *o*, and the current will cease to flow; the core of R will lose its magnetism; A will rise, pulled up by a little spring, and the ink mark will cease on the paper. Thus a short depression of M, will make a dot and a long depression a dash. The handle M, in the diagram does not appear to touch *m* or *o*. In practice it is always touching *o*, when not depressed to touch *m*.

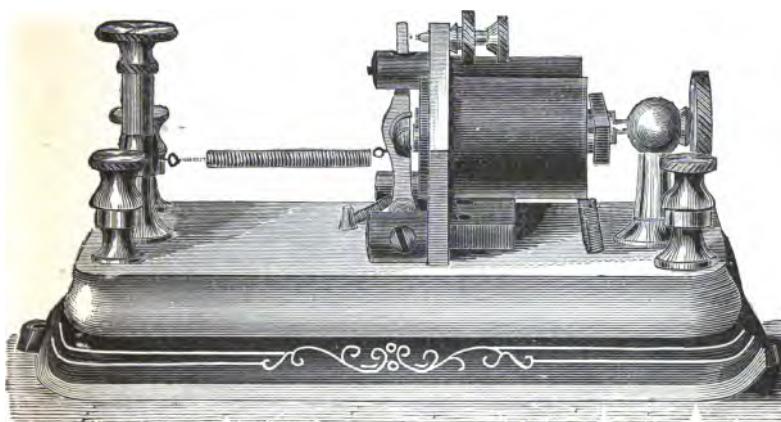
"There is constant loss of electricity in telegraphy, owing to imperfect insulation and moisture of wires, insulators, etc." "This loss is called escape, and would be a very serious matter but for the application of relays or automatic repeaters."

"If you have a coach to drive fifty miles, your horses get very tired and cannot keep up their speed, after going, say fifteen or twenty miles." "In order to make time, therefore, you stop and put on a fresh team." "This is very like what has to be done on long telegraphic circuits." "The new team is a battery at some intermediate point; and the electricity is turned on to the line

through a relay." In fact, but for relays, messages would have to be written down and repeated often, especially in wet or murky weather, and the service would therefore be slower, more costly, and more liable to mistakes in transmission."

"Here is a diagram of a modern relay:"

FIG. 19.



RELAY.

"As a matter of fact, there are intermediate batteries in at least two places, on the through Chicago and New York wires." "These local batteries are attached by wires to the relays, the current going forward as the current goes forward from the original sending station, whose sending wire is also attached." "The new stream of electricity, so to speak, propels the message forward."

"I do not know as I comprehend that," interrupted Ned; "Will you explain it again?"

"Well," replied Voltagal, "I will illustrate it in another way." "Suppose there was a pond of water at Englewood and some one wanted to build a mill at some point twenty miles away, to be run by water from that pond." "The party would then dig a canal from the pond to the mill; but suppose when the water came to be turned on to the wheel at the mill, it was found the power was too little; the proprietor in looking about to remedy the fault, discovers another pond half way between the first pond and his mill and

proceeds to dig a canal or trench to connect with his main canal." "He does so, and his water-wheel moves as he desired." "He has turned on more water, which is more power." "That is just what the electrician does; he turns on more electricity and signals are repeated with the required force."

"The electric telegraph has become an actual necessity of the advance of civilization." "It is used not only to transmit messages from point to point, but in a city becomes a fire alarm; regulates clocks; calls guests in hotels; tells the police to send patrolmen or wagons to certain points, and regulates upon railroads the movement of trains." Silently and quickly, the sympathetic current pulsates and throbs and the great force which man fears and dreads when loose in the sky, he harnesses so that a child can handle it and make it do its bidding."

"Ned," said Voltagal, very gravely, "Notwithstanding all this, man knows nothing of what it is or why it is." "Day by day, he discovers new uses for its wonderful force and new means of applying it, and yet the genius has not arisen who can produce it economically, so that it may take the place of wind and of steam." "Will you be the man?" "Just think, Ned, of the vast stores of natural energy running to waste in the great waterfalls of the world, which may be applied, yes, will yet be applied, to the production of electricity, which transmitted without appreciable loss, will move machinery a thousand miles away."

"Watt-stephen you found enthusiastic about steam; what is it compared with the great force I represent?" "Nothing, nothing." "Steam must have coal or wood, and forests and coal-beds disappear as by magic, as the wreaths of vapor go into the sky from the escape pipes of the engines of the world." "The coal and the wood are lost in these forms and will never be replaced." "The waterways of the world will furnish power to generate electricity to meet all the wants of man for power, and nothing is lost; the great fountain, unlike the coal mine, will never be exhausted."

"In explaining the mode of operation of the telegraph, I have not alluded to any other than the Morse system."

"There are many other forms of telegraphy and many other modes of producing electricity besides those I have recited to you."

"It would be profitless to you to explain all these various

devices and means." "My object has been to set you to thinking and studying, for I know you will master the subject by and by; but I will hastily mention that messages are not only sent telegraphically by dots and dashes, which represent, as you have seen, the opening and closing of currents, but a man's handwriting may be sent; the messages can be printed, or needles be moved or deflected in an arbitrary manner, so as to represent letters."

"Music and the human voice can be transmitted, and men are now experimenting on sending the images of things, but thus far without much success."

"The instrument employed is called the Photophone, and the principle resides in the sensitiveness of the metal, *selenium*, to light."

"You talked through the telephone with your mother, and I promised to explain its working to you. I will now do so, and I want you to give me very careful attention; and if there is anything you do not understand, interrupt me, and I will try to make it clear to you. Meantime I hand you drawings of parts of the instrument necessary for the transmission of human speech."

"There is a fascination in the telephone, which by the way, is derived from Greek words, which mean far, far off, and sound or voice." "Hence an instrument by which you can hear the voice from 'far off.'" "You already know that sound is caused by vibration, which is appreciable to the ear."

"Let me tell you very simply, the manner in which sounds are made evident to the sense of hearing." "The external ear has little or nothing to do with the auditory apparatus." "Birds hear as well as horses, but they have no external ear." "The outer passage of the ear is closed by a membrane which measures about one-third of an inch in diameter." "This membrane receives the impression of the waves of sound, vibrating as these waves strike it." "This membrane, thus vibrating, communicates its motion to a series of small bones, which in their turn act upon the fluid contents of the internal ear." "Within this fluid are spread out the extremely sensitive fibers of the auditory nerve, the duty of which is to convey to the brain the impression of sound."

"Understanding this, you will more readily understand why we can talk through the telephone."

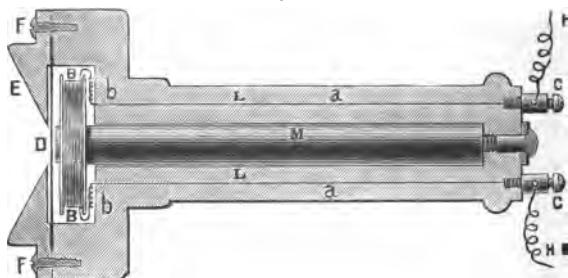
"You know you have found that an iron bar, if wound around

by an insulated copper wire, becomes a magnet whenever an electric current is passed through the wire. It becomes magnetized and de-magnetized instantly."

"There is one thing about the magnetized bar, though, that I did not tell you, and that is, that when magnetized, it is lengthened; and when de-magnetized it shrinks." "This is not perceptible to the eye, but it is true, nevertheless."

"If the magnetized bar is sufficiently large, it will click at every pulsation, so to speak, of the electricity in the wire around it." "This fact brought about the discovery that musical notes could be sent by electricity." "The telephone in most general use, and which I shall describe to you, Ned, was introduced by Prof. Alexander Graham Bell, and bears his name." "I give you herewith a sectional or interior view of the apparatus."

FIG. 20.



SECTIONAL VIEW OF BELL'S TELEPHONE.

"As you see, Ned, the telephone proper consists of a steel cylindrical magnet, M, which is about five inches long and three-eighths of an inch in diameter, encircled at one end by a bobbin, B, B, on which is wound a quantity of very fine, insulated, copper wire." "The magnet and coil are contained in a wooden or hard rubber cylindrical case, L, L."

"The two ends of the coil, b, b, are soldered to thicker pieces of copper wire, a, a, which traverse the outer envelope from one end to the other, and terminate in the binding screws, C, C, at its extremity."

"Immediately in front of the magnet is a thin, circular piece of iron plate, D, which is kept in its place by being jammed between the main portion of the outer case and a wooden or rubber cup,

carrying the mouthpiece or trumpet, E." "These two parts are screwed together by the screws, F, F." "The mouthpiece is cut away at the center so as to expose a portion of the iron plate, D, about half an inch in diameter." "This iron plate is what photographers call *ferrotype*." "The transmitting and the receiving telephone, as devised by Bell, are exactly the same in construction." "When sonorous undulations strike the iron plate of the telephone, the plate is set to vibrating." "Its particles move to and fro in some way or other."

"Whether these motions are simple or complex, depends upon the air from which they are derived." "We will assume that the plate has simply a pendulous, or swinging, motion." "The iron plate in the telephone is placed, not against, but close to the extremity of the steel magnet." "This makes the iron plate a magnet by induction, and as it vibrates, its magnetic power is constantly changing, being alternately, as it moves back and forth, stronger and weaker." "When a magnet moves in the neighborhood of a coil of wire, the ends of which are connected together, an electrical current is developed in the coil, whose strength depends upon the rapidity with which, and the distance through which, the magnet moves:"

"So you see, Ned, that when the plate moves near the coil of wire, a current is induced in the wire which traverses the whole length of the connecting wire which binds it to the distant instrument; when the plate recedes or returns from the coil, a reverse current follows the first." "The intensity of these currents depend on the rapidity with which these movements are effected, and are also largely influenced by the fact, that the plate keeps changing its magnetic strength in its movements to and fro."

"Under these circumstances, it follows that the induced currents, alternately *positive* and *negative*, follow each other in a uniform succession and with a rapidity which corresponds to the pitch of the note that has excited the diaphragm of iron."

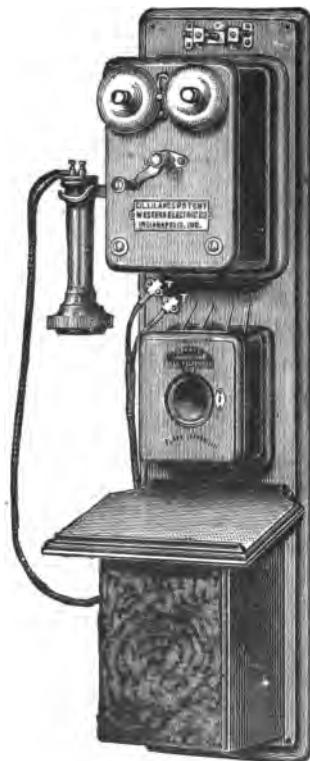
"These currents pass along the circuit and circulate round the coil of the distant telephone, where they modify the magnetic relations between the steel magnetic core and the iron plate, in such a way that one current, for instance the *positive*, attracts the plate, while the other, the *negative*, repels it." "As these arriving currents follow, first *positive*, next *negative*, in orderly succession.

the plate vibrates in a uniform manner and will perform the same number of vibrations per second, as did the plate of the sending instrument."

"Hence the sound heard at the receiving station must be exactly the same as that sent from the sending, except in loudness."

"The different iron plates vibrate in exactly the same manner."

FIG. 21.



COMMON FORM OF TELEPHONIC APPARATUS.
As manufactured by the Western Electric Co.

"This is all there is in the phenomena displayed by the action of the Bell telephone."

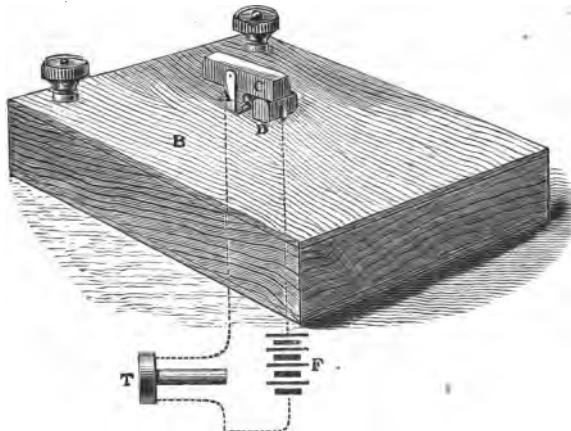
"The action is simple, yet it is most marvelous that so faint a current, or in fact any current of electricity, will allow the waves of sound to be carried hundreds of miles over an iron wire."

"The diagram which I give you shows the common form of

the telephonic apparatus in use ; you will notice that the transmitter in this is not like, in form, the receiver which hangs by the side of the case." "What is usually and popularly called the Bell Telephone, because the use of the instruments are licensed by the Bell Company, is composed of a carbon transmitter and a Bell receiver."

"To show you how sensitive these pieces of carbon are, and to explain what I just told you, I give you a diagram which I will call a Microphonic Sounding Board."

FIG 22.



MICROPHONIC SOUNDING BOARD.

"A piece of carbon, C, is very delicately balanced on an axle A, the carbon C, resting on another piece, D."

"This apparatus rests on a sounding board B, and the rest of the circuit is arranged as shown with the voltaic cells, F, and the Telephone, T. A fly walking over the board causes sounds to be heard in a telephone quite a distance away, because of the change of resistance which occurs between the carbons C, D."

"I know, Ned, this is hard to believe, but the same principle has been applied to the detection of counterfeit coins, and the weighing or discovering of a difference in the weight of coins where such difference is too small to be detected by any weighing scales." "In fact the instrument employed, which is called the

Induction Balance, is so sensitive, that you may take two golden eagles right from the mint, rub one hard for a moment between your thumb and finger, and the machine will detect the loss resulting from such contact."

"I think," said Ned, "that that is wonderful; but as everything connected with electricity is wonderful, I am not surprised at the idea of hearing a fly walk."

"The carbon transmitter, or *microphone*, acts on the principle that a variation in the resistance of a voltaic circuit, may be caused by the variation of pressure between two surfaces in contact; and that this variation of resistance will cause a corresponding motion in the disc of a telephone included in the circuit." "In the *microphone*, the telegraphic circuit includes a voltaic battery, a telephonic receiver and two pieces of carbon lightly pressed together."

"This carbon is generally metallized by being heated white hot and plunged in mercury." "These carbons press more or less strongly on each other, when the voice sets the diaphragm in motion, and so modifies the resistance of the circuit, as to set the telephonic receiver in action, reproducing the sound by means of its vibrating disc."

"As I have seen electric lights, won't you please tell me about them, for I would like to know how to light mamma's parlor with those queer, pear-shaped lights I saw in the city."

Voltagal smiled, as he said, "Ned, you are a very ambitious boy, and I will with pleasure tell you all about the light of the future, though I greatly fear you will have to forego lighting your house by it, until you get one of the steam engines, Watt-stephen told you about."



CHAPTER VII.

"We have found," resumed Voltagal, "that when the terminal wires of a battery of considerable magnitude are brought together and then separated slightly, that there results from such union and separation, an intense bright light." "This light takes on a curved form, and it has in consequence been named the electric arc."

"If the circuit remains open, the wire becomes intensely heated and soon drops off in melted globules." "To a certain extent the wire also becomes also volatilized and passes off in vapor, the color of which is determined by the kind of metal the wire is composed of and the medium in which the experiment is made."

"As the wire melts away, the distance between the points increases, and soon the space between becomes so great the light is interrupted because of the too great resistance of the air between." "Bring the wire together again, and separate as at first, and the light continues."

"Now in this lies the discovery of the electric light; and in the course of thousands of experiments man has found that carbon points, instead of wire, are best for the production of the light."

FIG. 23.

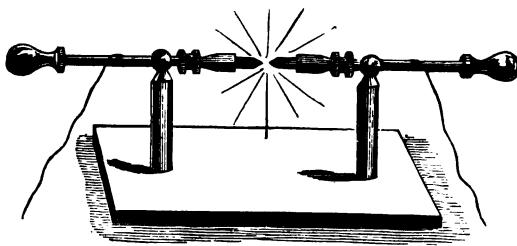


DIAGRAM.

"I give you a diagram, which shows the arrangement of the battery wires and charcoal or carbon points for showing the electric light." "You see it is very simple and easily constructed."

"Now remember, Ned, there is no light until the points of charcoal touch each other, when they are slightly separated and the arc light glows with intense heat."

"In burning these points, you will discover that one burns away more quickly than the other; in fact, nearly twice as rapidly."

"Knowing this, and also knowing that to obtain a constant light, the points as they burn away must be made to approach each other just as fast as they burn away, led to the construction of mechanical apparatus, to feed them, so to speak, at a certain rate to the flame."

"Until 1842, the electric light was produced only experimentally; but in that year what are known as the Grove and Bunsen batteries were introduced, from which a constant stream of electricity was produced and at less cost than before; these batteries were used largely to produce the arc light."

"Nevertheless, the light was still too costly for common use; and experimenters went to work with a will to find some new source from which to produce electricity, in large volume and cheaply."

"I have told you that electricity has the power to evoke magnetism, and that Farady discovered that magnets would induce an electric current without the intervention of any battery."

"So as to get a new and large stock of electricity, inventors first caused a magnet to spin rapidly round before coils of copper wire; but they were not slow to discover that it was better and more convenient to keep the magnet or magnets stationary and to have the coils of wire perform the active work."

"The combination of coils constitutes the armature of the machine." "As the coil or coils approached or receded from the magnet, two currents of electricity would be induced, each flowing in a different direction."

"To obviate this, an ingenious machine, called the commutator, was invented, which turned these alternate currents into one having a uniform course."

"These early machines were, however, of but little practical value; they were, in fact, hardly more than expensive toys; but like all such early machines or devices, they stimulated inquiry and thought and thus mark the path of human progress."

"I said the coils were the armatures; at first these were wound transversely on the bobbins, that is in the same way as an ordinary cotton spool is wound." "Siemens placed the coils lengthwise or from end to end of the iron core and got from such arrangement an immense increase of electrical power."

"Up to that time the magnets used in the machines had been what is called permanent magnets, rather a misnomer, since the magnets did really lose their power from year to year." "A Mr. Wild, then hit upon the idea of using *electro-magnets* for the machines, exciting them by the current induced by permanent magnets."

"The first magnet excited, acted upon a second and more powerful one; this in its turn induced a current in a third, thus establishing a powerful magazine."

"The Gramme machine, which came in turn as an improvement, differed from the Siemens machine in this, that it gave a direct current like that afforded by a voltaic battery, instead of alternate currents." "While this is not so much of an improvement for lighting purposes, since an arc light can be maintained, owing to the rapidity of change of the currents, it is essential to the electrotyper or others using a machine for electro-chemical purposes, as for such, the current must always be in one direction."

"The armature of the Gramme machine takes the form of a ring, which is formed of a bundle of iron wires, bound with insulated copper wire in sectional coils, the end of each coil being connected with copper slips, which are prolonged upon the axis on which the ring rotates." "This ring is magnetized inductively by the near presence of powerful electro-magnets, and the currents are collected by metallic brushes."

"The Siemens machine, has an armature which consists of coils wound on a hollow cylinder of iron and its four field-magnets embrace it within them." "These machines and all others of like character are run by steam power and are known as dynamo machines and employ electro-magnets, instead of permanent magnets." "The arc light is used for lighting streets, or large areas, and is intensely bright; one horse power of the steam engine will produce from the best dynamos, 1,000 candle light."

"The incandescent light, is an electric light produced by burning platinum wire or some form of carbon, in a glass bulb, from which the air has been exhausted." "Edison, experimented with platinum and with bamboo rod, cut the length required and deprived of its hard silicious coat." "This bamboo, split until about as fine as the hair in the mane of a horse, he placed in a mould formed by cutting a U-shaped depression in a plate of nickel, another plate covering it over."

"He then placed it in a furnace and subjected it to a heat which carbonized the bamboo." "His incandescent lights are those pear shaped lights you spoke about; the electricity is generated by an electro-dynamo machine."

"Electric lights would come into general use but for the cost of the power necessary to generate the electricity." "It is in this direction that future inventors must labor and I hope Ned, you will be the one who can produce electricity so cheaply that it may light all homes and propel all machinery." "Do not be discouraged if your first efforts are failures." "Remember that the subject of an electric telegraph was broached as far back as 1753 ; but it did not become a success until after 1840." "In 1858, the first cable was laid across the Atlantic ocean and a few words were transmitted ; it then ceased to act and it was not until 1866, that the first cable was successfully laid which proved a commercial success." "We have seen that the real reason why electricity is made useful to man is because it has two properties, one *negative* and one *positive*." The negative repels its kind and attracts its opposite ; the positive likewise."

"Hence the *positive* current can cross a continent carrying a message, which delivered, it goes into the earth to find its mate, the *negative*." "It is not at rest until it unites."

"Oh! dear me," sighed Ned, "I shall have to study hard to grasp all the possibilities which this fact contains ; but rest assured that I will try to comprehend its nature and its marvelous force."

Voltagal, was busy packing his valise, when Ned opened the state room door to look into the body of the car.

The old man was still asleep in his berth ; and Ned began to wonder, whether he would awake before they reached Kansas City. Just then the whistle sounded and Voltagal, looking up remarked, "that old gentleman seems to be sleeping soundly ; let us wake him up" and he placed one end of a wire in Ned's hand saying, just touch him on his big toe which you see protruding from the bed." Ned did so, whereupon the old man gave a sudden start, uttered the words, "what is the matter" and rolled upon the floor. Ned laughed and a general titter ran through the car, at the ludicrousness of the scene.

With a start, Ned awoke ; the light was streaming into his room and he lay sprawling upon the floor.

His mother stood by his side and as he opened his eyes and exclaimed, where is Watt-stephen ? where is Voltagal ? she remarked, "my boy has been dreaming."

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